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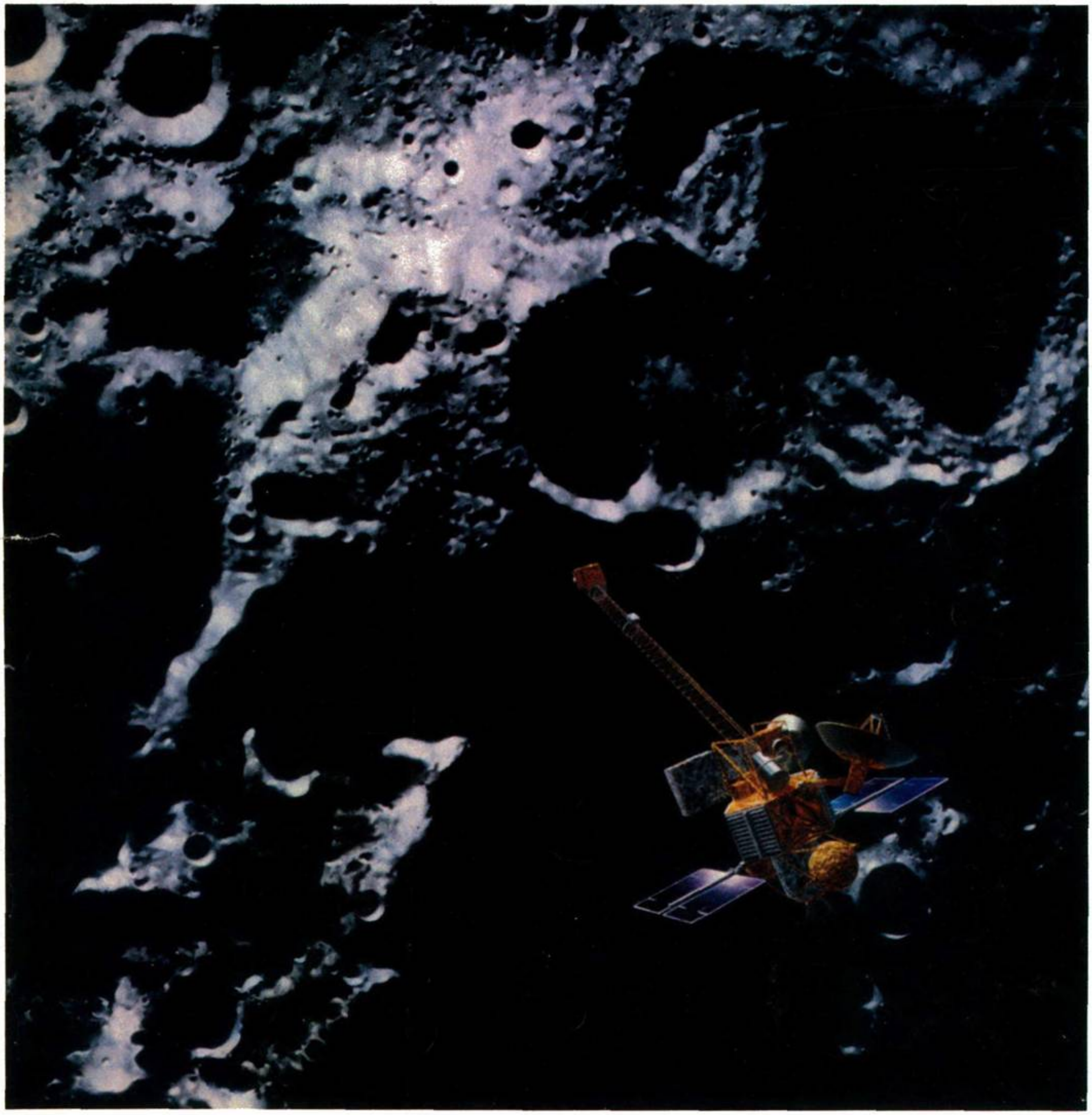

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“My experience with Meade Instruments is consistently on a higher level than with other astronomical equipment manufacturers. One Meade product is so outstanding I must comment on it. **The Meade Series 4000 eyepieces are clearly the finest eyepieces available.** I have owned or used just about every other commercially manufactured Plössl eyepiece, and one does not need to be a seasoned observer to immediately notice the difference.”—**Michael Barnett, Westlake Village, Calif.**

“Several hundred amateurs had the chance to test the performance of Meade Series 4000 eyepieces at the Astrofest Telescope Convention. Observing Jupiter with your Ultra Wide 8.8mm on a 7″ f/9 Starfire refractor, the huge 84° field encompassed the entire Jovian system. The four moons were resolved as discs, perfectly round even at the extreme edge of the field. Jupiter itself presented a magnificent show with a multitude of bands, small ovals, and festoons, etched in high contrast on the planet's surface. Meade Ultra Wide Angle eyepieces are a unique design that really bring out the best in a high performance telescope.”—**Roland Christen, President, Astro-Physics Corp., Rockford, Ill.**

“Due to annoying field curvature in my Dobsonian telescope, I returned a competitor's 24mm wide-angle eyepiece, and ordered a Meade Series 4000 Super Wide Angle 24.5mm. To my delight the Meade ocular essentially eliminated field curvature while maintaining “Plössl-like” edge to edge sharpness. I now also own the Meade Super Wide 13.8mm that has absolutely the flattest field I have ever encountered in a six-element wide-angle eyepiece. I was skeptical at first of your claims that the Series 4000 are the best eyepieces, but am now a believer.”—**Richard D. Clark, Grand Junction, Colo.**

“As a former staff member at Mt. Wilson and Palomar Observatories, I have had access to some of the finest optics, including eyepieces, ever produced. When I performed some critical evaluations of the Meade Series 4000 eyepieces, it was immediately apparent that as a result of these eyepieces, the telescopes used for my tests were operating at a new visual performance level. With regard to such parameters as image contrast, definition, field flatness, and secondary spectrum, without exception these eyepieces achieved the highest level of professional precision. I find it rather difficult to comprehend there being any room for future improvement.”—**Paul Roques, Williams, Ariz.**

“I had the opportunity to compare your series 4000 eyepieces with those of the other premium brand. Comparisons were made using DFM Engineering 16″ and 18″ telescopes at the University of Colorado. A wide range of focal lengths were compared, but I found the Meade Series 4000's to be preferable in all cases. The Meade eyepieces had less color, gave better definition, more field of view, and more comfortable eye relief. In addition the Meade Super Wide Angle 40mm provided noticeably more field than did the competing brand's; measurements against a star field verified this fact.”—**Dr. Frank Melsheimer, President, DFM Engineering, Inc., Longmont, Colo.**

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GALAXIES LIKE M81 and M82 in Ursa Major contain variable stars that the *Hubble Space Telescope* will study to help astronomers calibrate the distance scale of the universe (see page 38). Photo by Tony Hallas and Daphne Mount.

COVER: The 1990s will see extensive, in-depth exploration of the solar system following the last three decades of get-acquainted missions.

ASTRONOMY®

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The Audit Bureau

Behind the Scenes

AN EXCITING DECADE AHEAD

With the post-*Challenger* recovery of the American space program and the rise of Soviet, European, and the Japanese space efforts, a new era in the exploration of our universe begins. The old era was the era of firsts: the first visit to the Moon, to Mars, to Jupiter, and to Neptune. It was the first infrared sky survey, the first look at the universe in gamma rays.

The new era will be an era of returning to worlds that we have already visited. We'll be flying to Jupiter for the fifth time with *Galileo,* and *Cassini* will be our fourth journey to Saturn. Even more spacecraft have been to Venus and Mars.

Second? Third? Fourth time? What's left to discover? Don't we know what's there already? Hardly.

The missions of our first decades in space gave no more than a tantalizing glimpse at the worlds that orbit our Sun. The first x-ray telescope, the first infrared survey of the heavens, the first gamma-ray observatory told us only what to look for the next time, the second time, when we would return for a good, long look. So much is waiting out there for us to discover.

The *Hubble Space Telescope,* for example, promises to change our view of the universe — to revolutionize observational astronomy. Some things we can predict. Astronomers expect to calibrate the distance scale of the universe and look farther back in time to observe the evolution of galaxies — that's all been planned.

But the real question is what will *HST* find that no one expects? Or *Magellan*? Or *Cassini*? And what about *Galileo* — does anyone believe for even a moment that *Voyager* discovered everything worth finding at Jupiter? Certainly not. *Galileo* and *Magellan* and *Cassini* and *HST* will explore worlds and galaxies in greater detail than ever before. What they will find we simply can't even guess. Isn't that what "discovery" means?

But we can be sure of one thing. As we humans extend our vision farther outward into the universe, and as we explore more closely the worlds that orbit our Sun, we will find new things, things that we never even dreamed of before we looked. Thus it is all but impossible to predict what astronomy will be like at the end of these next ten years. Stay with us and find out.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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Letters

Up the Milky Way without a Paddle

When I first set up my new telescope, I could not find Polaris. Only after I installed a Telrad did I begin to see the light. Fortunately, I read "Tricks of an Observer's Trade" by Steven Forrest (August 1989) at the time of my greatest need. He told of an experience similar to mine and advised, "More than any other purchase, that zero-power illuminated reticle gave me access to my telescope."

I continue to enjoy astronomy. I feel that if novices can get off to a good start, there will be fewer burnouts among us. In the beginning I was lost in the night sky without a paddle. Now I use a Telrad. I encourage the telescope industry to acquaint their new customers with this device. — *James A. Stewart, Carlisle, Ohio*

Keep Your Perspective

I read "ASTRONOMY Surveys Twelve Small Refractors" with great interest. I agree with your findings as they pertain to non-beginners, but I fear you may have scared away some would-be beginners. The prices quoted for "acceptable" telescopes were high for people just starting out in a field that they know nothing about.

When I was eight years old, I received my first view of the Moon through a small, wiggly spotting scope set up on a picnic table. At that moment I knew I would buy a telescope. I saved for two years and bought a small refractor. This telescope probably wouldn't do very well on the tests listed, but for a small child it was everything I wanted and could afford. It's twenty years later and I have an 8-inch Schmidt-Cassegrain. If I hadn't looked through that small, wiggly spotting scope or purchased a small, imperfect refractor, I may not have grown up to love the science of astronomy.

For the beginner, I think any view is better than no view at all. Remember that even those small, imperfect telescopes are far better than the telescope used by Galileo. — *Forrest Bently, Minneapolis, Minnesota*

Cold Camera Query

I am delighted with your new equipment reviews. I live in an astronomical backwater and can either drive several hundred miles to a camera store that carries telescopes or be at the mercy of mail-order suppliers. Your honest assessments of equipment are most welcome.

I do have a question about the cold camera you reviewed ("ASTRONOMY Tests the Northern Lites Cold Camera" by Robert Reeves, July 1989). How do you prevent the film from fogging when you

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There's no question large aperture reflectors like John Vogt's excellent 30" f/3.8 produce deep sky views rivaling those I've seen in major observatories. But his scope, like yours, is limited in field sharpness. The main offender is coma, an aberration which makes stars look like blurry comets. Visually and photographically, the faster the scope the worse the effect.

If we compensate for coma before starlight reaches the eyepiece, then the best eyepieces will be used to fullest advantage, and a sharp full frame 35mm photograph is possible. In sum, my design goals were:

1. maximum reduction in coma and field curvature without compromising spherical aberration and color correction

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—Al Nagler

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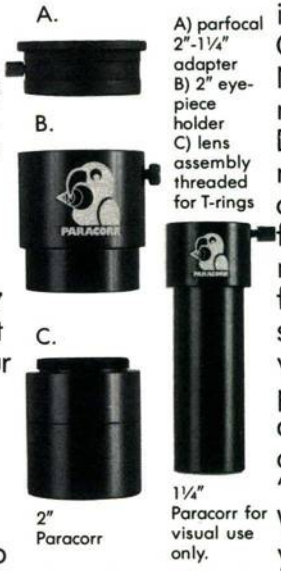

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install or remove the camera from the shutter assembly? — *S. D. Ellington, Yelm, Washington*

— Use a hair dryer or a car heater to rewarm the film after you take the exposure and before you advance it for the next picture.

And Then There Was Light

After reading "Court Rules against Light Polluter" (Amateur News, July 1989), I became confident that my group can take action against a light trespasser that has recently affected our observing area.

I observe in downtown Philadelphia at the Franklin Institute, a museum where interested children and adults can go to learn about and experience science. All was going well until a new building came along. The building is three times the size of the Institute and its lights flood the entire roof of the building where the observatory is located.

Thanks to your article, we now know that we may be able to remedy the situation and justice will be served for some loyal skywatchers. Before we read your article, we thought the courts would just throw the case out the window. — *Christine Bielawski, Philadelphia, Pennsylvania*

Corrections

The article "From Footprints to Footholds" by Robert Nichols (July 1989) gave a fine account of the prospective return to the Moon. Astronomy should ultimately be a thriving activity at a lunar base.

However, please note one correction. I am quoted as saying, "the lion's share of frontier astronomy could be done from the Moon as early as 2015." What I actually said was 2050, an easy confusion for someone on the other end of a phone line. But I will also be surprised and disappointed if we don't have some quite interesting and significant astronomy being done on the Moon already by 2015. — *Harlan J. Smith, Director, McDonald Observatory*

The address given in the Readings and Resources column (September 1989) for the "astrovideo sampler" was incorrect. The correct address is David Brewer, P.O. Box 295, Lake Helen, FL 32744.

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

Viewpoint

THE MANY ROLES OF THE AMATEUR

by Robert E. Stencel
Executive Director of the Center for Astrophysics and Space Astronomy at the University of Colorado at Boulder and coordinator of the Front Range Astronomical SuperCluster, a coalition of eight regional astronomy clubs

The question has been posed, "Can amateur astronomers contribute to the field of astronomy?" The answer is a resounding, enthusiastic, no-reservations "Yes"! By providing needed scientific data as well as educational and public support, amateur astronomers bolster and sustain certain areas of astronomy that otherwise would go wanting.

The simple fact is there are too few professional astronomers and even fewer large telescopes to monitor all the events occurring at any one time in the sky. As soon as a new telescope is built or launched, observing time is at a premium. And increasingly, the "glamour" targets — starburst galaxies, x-ray sources, etc. — are the big winners in the competition. Long-term projects like variable-star observing or comet searches are simply too time-intensive for already oversubscribed large observatories.

From counting meteors to educating the public, amateur astronomers do make a difference.

Groups like the the American Association of Variable Star Observers and the International Amateur-Professional Photoelectric Photometry in the past were considered to be congregations of hobbyists and "armchair" stargazers. Increasingly, though, professionals have realized that real research — in the form of magnitude estimates for variable stars, planet monitoring, and supernovae discoveries — is coming from those hardy souls all over the world who operate small telescopes and personal observatories.

Simple projects such as meteor counts, crescent Moon sightings, and eclipse observations are also of value to professional astronomers, because the reports provide fundamental data that otherwise might not be collected. Organizations like the American Meteor Society, the International Occultation Timing Association, and the Association of Lunar and Planetary Observers rely on amateurs to build their databases. Professional astronomers increasingly consult these databases before they begin their research because some of the data they need may have already been gathered.

One important point should be added. When amateurs make a commitment to work with professionals, they pledge that they will supply the best data that they possibly can. The amateur who wants to contribute to astronomy must be as dedicated to this aim as he is to enjoying the hobby. That means keeping current with literature, using sky maps that are up-to-date, and delivering the promised data in a timely fashion.

The other area in which amateurs excel is their ability to be heard. Their voices are often listened to when those of the professionals might not be. Given the state of science education in the United States, amateurs are a light in the darkness. Their enthusiasm translates to newsletters, star parties, public lectures, and even mall demonstrations. A child who is given the opportunity to stargaze, understand telescopes, and eventually help with observing among friends, will not grow up with science phobia. Exposure to science and its methods will help everyone cope better in a technical world.

The political influence of amateurs is something not to be overlooked. Committed organizations, like the Dark-Sky Association as well as amateur observing groups, have brought about positive changes in outdoor lighting policies that have helped cut the urban skyglow threatening such key research facilities as Palomar, Kitt Peak, and McDonald observatories. Public pressure has encouraged federal funding decisions on the space program, and that pressure can also help encourage the development of more scientific literacy in the schools.

The amateur's telescope is an invaluable tool, but his or her typewriter or word processor can be just as important. The current letter-writing campaign to commemorate the Very Large Array radio telescope on a U.S. postage stamp is a fine example of this.

Opportunities abound for the amateur. Coordinating the research, reporting results, and keeping the commitment to excellence are the essentials of science, whether professional or amateur. And in the end, it's the thirst for knowledge and the excitement of discovery that are the common bond for all astronomers.

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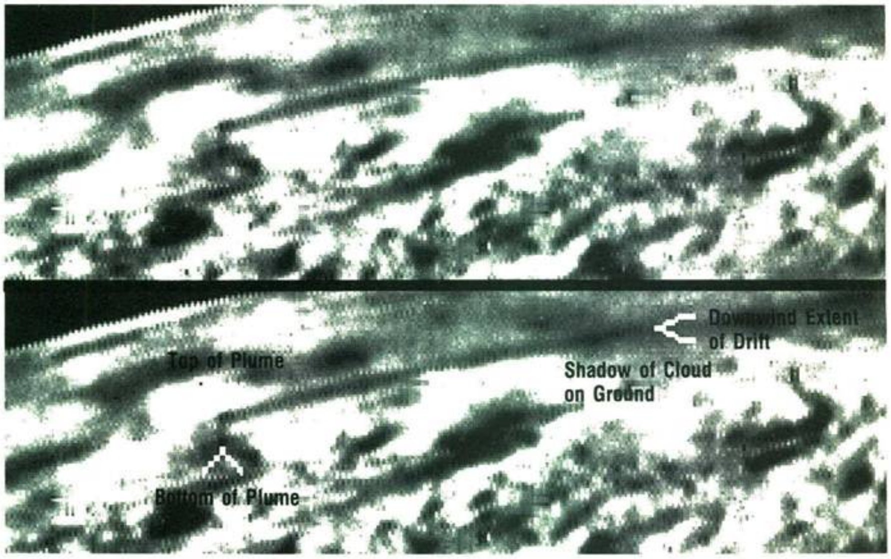

A BLACK PLUME OF MATERIAL erupts five miles into the cold methane sky of Triton, Neptune's largest moon.

An image taken by *Voyager 2* as it sped through the Neptunian system last August shows a five-mile-high plume of dark material erupting geyser-like from the surface of Triton, Neptune's largest moon. The image confirms what *Voyager* scientists had suspected: the dark streaks on Triton's surface result from still-active volcanism.

In the image the plume somewhat resembles a smokestack. It jets straight up nearly five miles before forming a cloud that is seen drifting about ninety miles westward on Triton's strong, nitrogen-methane winds. The feature was discovered when several images were compared and analyzed stereoscopically.

The plume is the first sign of active volcanism to be discovered on a solar system body other than Earth since *Voyager* found eight erupting geysers on Jupiter's moon, Io. Io's activity is driven by tidal stresses, but scientists are still attempting to explain what powers the plume on Triton. Before the discovery of the plume image, *Voyager* geologist Larry Soderblom summed up plumes (to explain the streaks) as "a crazy idea, but the best one we've got."

One possible explanation for the Triton plume is that nitrogen, held in a liquid state below the surface by pressure, could migrate to the surface through cracks or faults and erupt into vapor. As the nitrogen escapes, it could jet out dark, possibly carbon-rich particles and ice crystals from the depths of Triton. In this model, when the gas jet loses energy at about five miles' altitude, the particles form a cloud that streams downwind.

COMETS FROM CHAOS

Short-period comets may be driven toward the inner solar system by chaotic motions occurring within an extended disk of comets thought to exist beyond Neptune's orbit. According to a recent computer model by a University of Kentucky astronomer, the chaos is caused by gravitational perturbations of the four outer giant planets acting on the cometary disk.

Comets fall into two distinct orbital classes: long-period and short-period. Long-period comets have orbital periods over 150 years, while short-period comets have periods less than 150 years. The long-standing problem for astronomers has been reconciling the very different orbital characteristics of the two classes, especially in terms of the comets' origin in the solar system.

In 1950 Dutch astronomer Jan Oort neatly explained that the origin of long-period comets was a vast spherical cloud of some trillion comets located about 100,000 astronomical units from the Sun. Because it is halfway to the nearest star, the comets in the Oort cloud can be nudged toward the inner solar system by passing stars in our solar neighborhood. Because of their spherical distribution, Oort cloud comets can enter the solar system from any direction in the sky and circle the Sun in the same orbital direction as the planets (prograde) or in the opposite direction (retrograde).

More difficult to explain is the origin of short-period comets (those with periods less than 150 years). Unlike long-period comets, short-period comets are typically inclined about 15 degrees to the plane of the solar system. Moreover, out of the 121 known short-period comets, all except four — including Halley — orbit in a prograde direction instead of exhibiting both prograde and retrograde orbits as do the long-period comets.

The traditional explanation for the origin of short-period comets has been that near encounters with Neptune and Uranus divert Oort cloud comets into more tightly bound orbits in the inner solar system. Gradually, after subsequent orbits, these comets come under Jupiter's gravitational dominion.

But numerical simulations conducted in 1988 by Martin Duncan of Lick Observatory and Thomas Quinn and Scott Tremaine of the Canadian Institute for Theoretical Astrophysics at the University of Toronto showed that low-inclination, short-period comets cannot originate in the spherical Oort cloud. Instead, they proposed that a "comet belt" located in the outer region of the solar system was the source of short-period comets. They were uncertain, however, as to how these comets could be induced to enter the inner solar system.

The answer may involve chaos. In the October 1989 issue of *The Astronomical Journal,* Michael V. Torbett of the University of Kentucky, Lexington, reports that the gravitational tugs of Jupiter, Saturn, Uranus, and Neptune cause random motions in the comet disk that can lead comets to cross Neptune's orbit into the inner solar system. This random motion is referred to by scientists as chaos. In this case the chaotic motion originates not from the planetary perturbations themselves but from the motions within the comet disk.

"The perturbations caused by the planets are well determined," said Torbett. "But the exact ways in which those perturbations influence the comets is what causes the chaotic motion."

Torbett's model also indicates that the comet disk may consist of two components: a flattened disk and a scattered disk. Torbett calculates that the flattened

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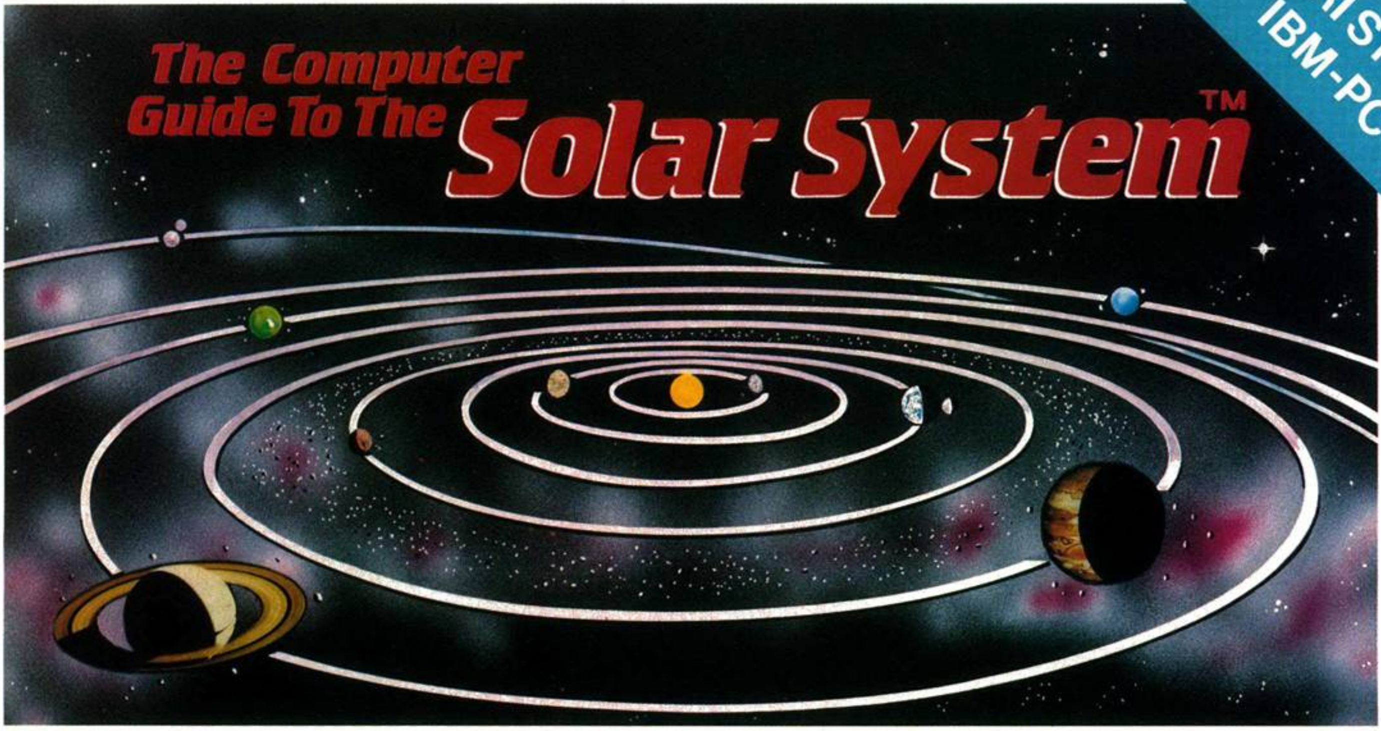

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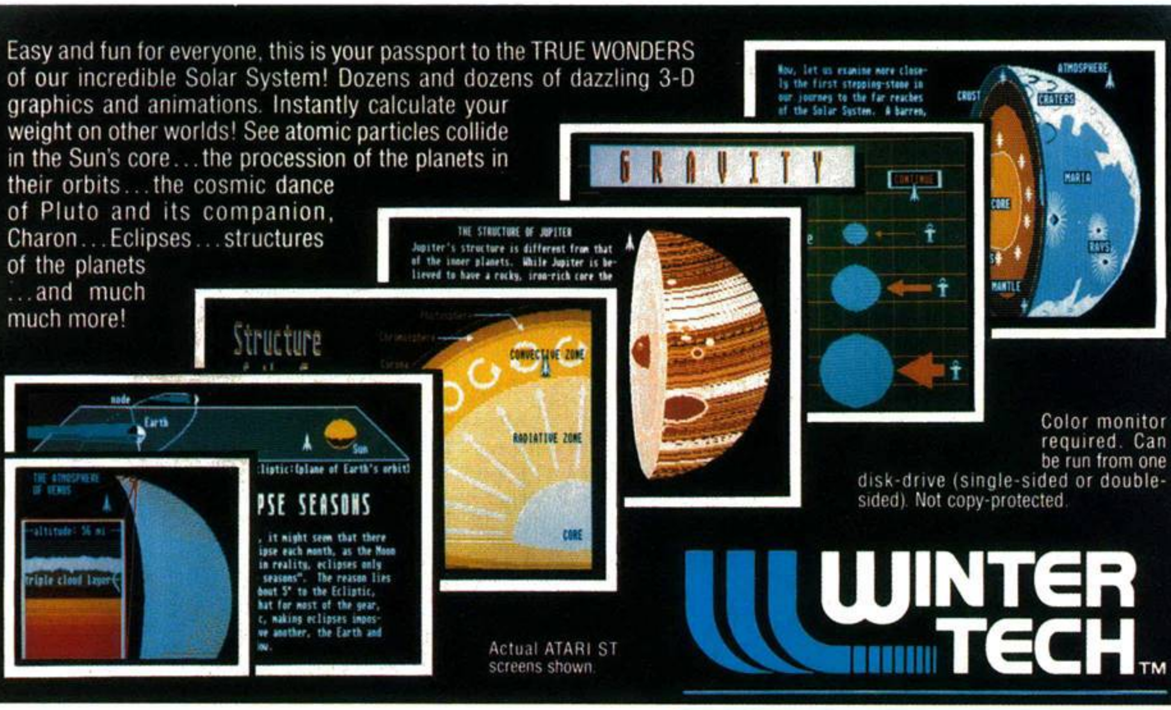

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disk, called the primordial disk, lies just outside Neptune's orbit — from 2.7 to 4.6 billion miles from the Sun — and is part of the original material from which the planets formed. The orbits of comets in the flattened disk would have low inclinations and small eccentricities (the latter term refers to a measure of the extent to which an elliptical orbit departs from being circular).

"The primordial disk is just an extension beyond Neptune of the disk from which the planets accumulated," Torbett said. "There's no reason why the primordial disk would end at Neptune. It could extend much farther out, but just never produced planets."

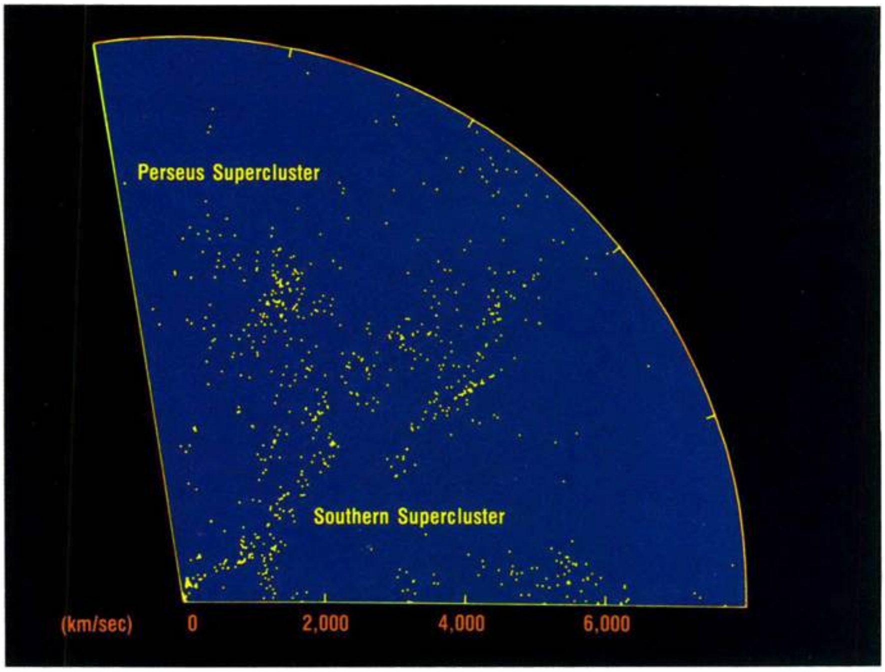
The scattered disk contains comets that are not strictly confined to the plane of the solar system but were scattered billions of years ago by near encounters with the evolving planets. The orbits of comets in the scattered disk have eccentricities and inclinations higher than those in the flattened disk (inclinations up to about 30°). Torbett suggests that the flattened disk is probably not replenished with comets but that the comets are dispersed to the scattered disk.

The zone of comets just outside Neptune's orbit, said Torbett, may be a source of the objects that bombarded the planets early in the solar system's history. The more distant regions of the comet belt, then, may provide the reservoir of short-period comets seen today.

SOUTHERN SUPERCLUSTER TRACED ACROSS SKY

A recent study of the Southern Supercluster of galaxies provides the first detailed description of this apparently rich and complex system. According to Shyamal Mitra of the University of Texas, the Southern Supercluster is a long chain of galaxies, the densest region of which passes through the constellations Cetus, Fornax, Eridanus, Horologium, and Dorado. The longest segment of the supercluster stretches across 123 degrees of sky.

Some 1,500 galaxies larger than 1 arcminute in apparent angular diameter and brighter than magnitude 15 were determined by Mitra to be members of the Southern Supercluster. The supercluster is subdivided into fifteen groups of galaxies, including the Fornax Group, which is the richest group. In addition, the supercluster has two segments, which Mitra labeled Region A and Region B. These regions are oriented perpendicularly to each other, with Region A being slightly closer to us than Region B. The total length of the system is 41 megaparsecs (133 million light-years) and its mean distance is 20 megaparsecs (65 million light-years), making it the nearest supercluster to the Local Supercluster, of which our Galaxy is a member.



A TENUOUS BRIDGE OF GALAXIES may link the Southern Supercluster and the Perseus Supercluster. This perspective is plotted from "above" the two systems. Recessional velocity in kilometers per second is given along the bottom. More distant galaxies have higher velocities. The depth of this slice is about 250 million light-years.

Mitra, who published his findings in the October 1989 *Astronomical Journal,* found that the Southern Supercluster is comparable to the Coma and Hercules superclusters in terms of mass and luminosity, but it is less massive than the Local Supercluster. The shape of the cluster, said Mitra, is not easy to describe because of its varied structure: it is neither a disk nor a filament. The best analogy is a "curved wedge that is narrow and thin at one end but broad and thick at the other."

Because of the Southern Supercluster's proximity to the Local Supercluster, some astronomers thought the two might be connected. Mitra finds this not to be the case. In two-dimensional plots on the sky, a portion of the Southern Supercluster appears to stretch toward the center of the Local Supercluster. In reality, this section actually extends farther out in space the closer it "approaches" the Local Supercluster's center; hence the two systems are well separated.

There does, however, appear to be some evidence that a stream of galaxies connects the Southern Supercluster with the Perseus Supercluster. But this connection, said Mitra, is tenuous at best, because so few galaxies are involved in the link.

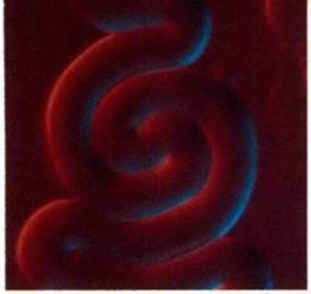
The existence of the Southern Supercluster was first pointed out by John Herschel in 1847, but it wasn't until 1953 that astronomer Gerard de Vaucouleurs recognized the band as a supercluster.

TURNING A CLASSROOM INTO AN OBSERVATORY

In the not too distant future, high school students will huddle around a microcomputer in their science classroom and study images of planets and comets taken the night before by an automated telescope controlled by the students. The images they will be looking at will be as good as the view through the Palomar Observatory's 200-inch telescope.

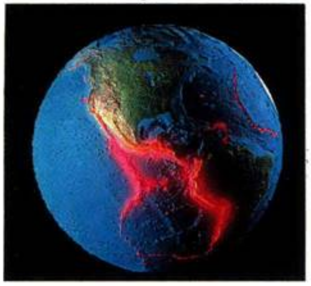
A research project to create sophisticated classroom-based observatories got underway this summer at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. With a grant from the National Science Foundation, the "MicroObservatory" project will design a new type of telescope that will put sophisticated observing technology into the hands of high school science students.

With the MicroObservatory students will be able to conduct actual astronom-

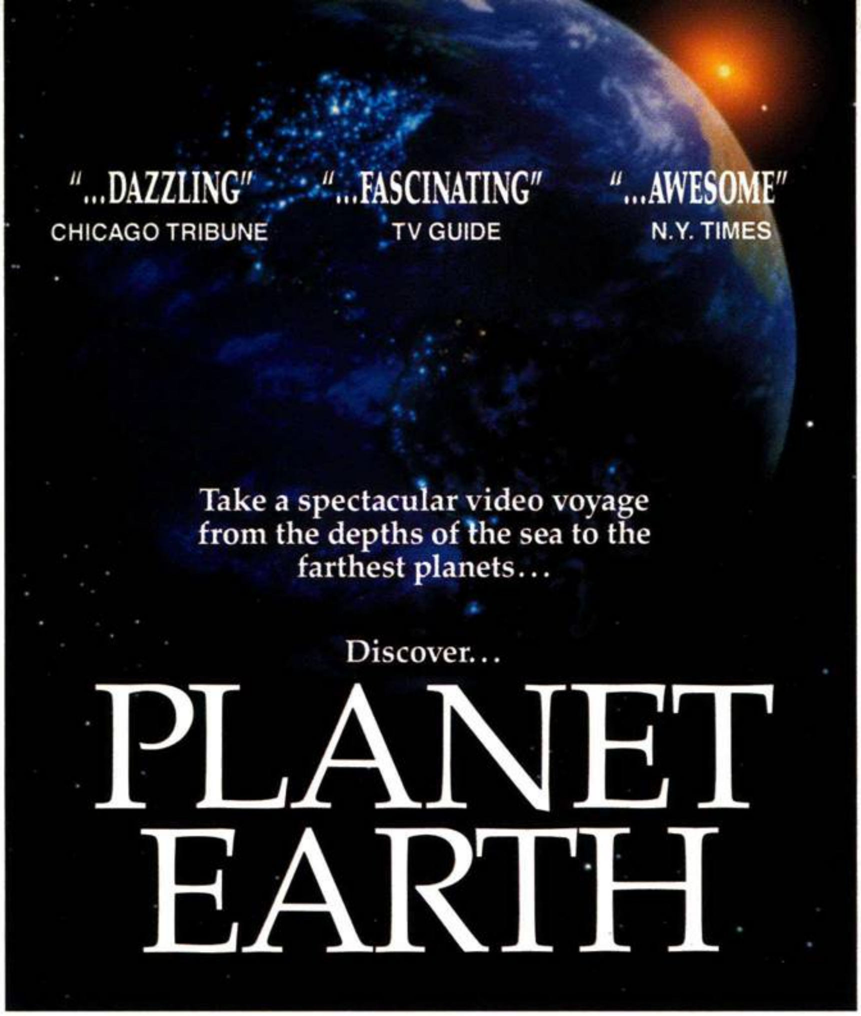


Test tube recreation of Earth's primeval chemistry.

Arizona's Meteor Crater: one of Earth's many asteroid impact sites.



An ancient "supercontinent" tearing apart to form today's world.



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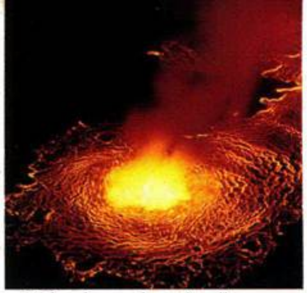
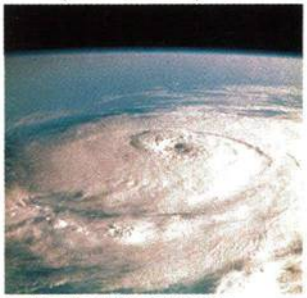
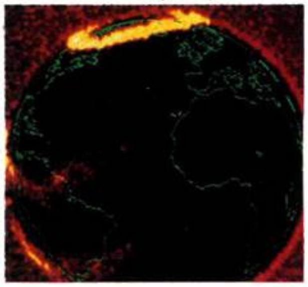


Molten lava rock continually reshapes the Earth's surface.



Earth's rotation helps create hurricanes, as seen from space.



"Northern Lights"... Earth's magnetic field clashing with the solar wind.

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ical research in such areas as variable stars, comets, asteroids, and lunar and planetary occultations. The instrument will be a 4-inch computer-controlled telescope combined with a charge-coupled device imager, a very sensitive light detector. With the capability to collect light from an object for as long as three minutes, the observatory will have the collecting power of a much larger telescope.

The MicroObservatory approach to classroom instruction is feasible because of recent advances in computer technology and the affordability of high-tech components like the CCD imager. The portable, weatherproof instrument is expected to weigh less than 35 pounds and cost approximately $5,000; computing power is furnished by IBM PC-AT or Macintosh microcomputers. Two prototype instruments will be built at the Center for Astrophysics and tested in Boston-area schools.

The Center for Astrophysics also recently received another NSF grant to establish a nationwide network of "resource agents," who will conduct workshops in astronomy education for teachers at all grade levels. The three-year program, called Project SPICA, will train a total of one hundred educators in summer workshops held at Harvard; the first workshop was held in August. These teachers will then train educators in their areas and provide them with information and materials throughout the school year.

Principal investigators of the two projects, Owen Gingerich and Irwin Shapiro of the Center for Astrophysics, are also involved with Project STAR, an NSF-funded program to create astronomy curriculum materials for high schools. (See "Astronomy in Our Schools" by Stephen Cole, September 1988.)

EARTH'S OLDEST ROCKS FOUND IN NORTHERN CANADA

Rocks with an age of 3.96 billion years have been found in Canada's Northwest Territories. They are roughly 160 million years older than the previous old-age record holders.

The newly discovered rocks narrow the gap between the time when Earth and the rest of the solar system formed (4.6 billion years ago) and the date of the first preserved terrestrial rocks. This gap is now only about 600 million years wide.

The discoverer, Samuel Bowring of Washington University in St. Louis, said, "There's a good possibility that even older rocks will be found, and our research group will be actively involved in hunting for them."

'SON OF SPACE TELESCOPE'

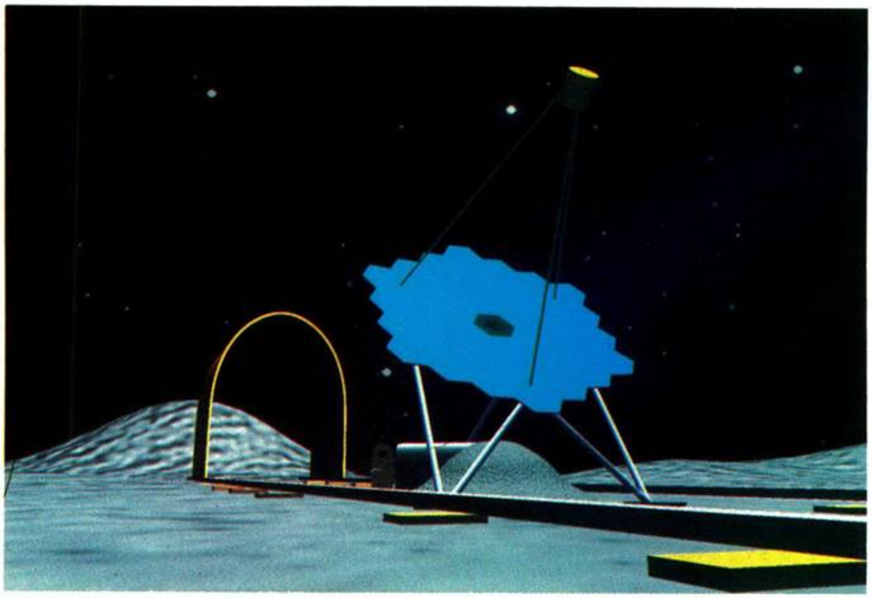
"The 1990s," said Garth Illingworth of Lick Observatory, "is the dawn of the golden age of astronomy." The *Hubble Space Telescope*, scheduled for launch in March 1990, will no doubt usher in a new generation of ground- and space-based supertelescopes that will extend our reach into the universe.

However, by 2005 *HST* will be approaching the end of its useful lifetime. With this in mind, Illingworth and fellow astronomers organized a three-day workshop in September 1989 at the Space Telescope Science Institute in Baltimore, Maryland. Their goal was to look beyond *HST* to the scientific goals and engineering challenges of a powerful second-generation space telescope that would go into operation sometime in the early twenty-first century.

Although no overall consensus was reached on the size of the second-generation space telescope, participants agreed that it should be at least 10 meters (30 feet) and possibly as large as 16 meters (52 feet) in aperture. The advantages of such a telescope in space would be significant. A 16-meter telescope on the Moon or in Earth orbit would resolve objects about seven times better than *HST*'s 2.4-meter (8-foot) mirror and more than fifty times better than the best ground-based observatories. And with a light-collecting area forty-four times that of *HST*, it would be able to detect objects as faint as magnitude 31.

The workshop featured lively discussions regarding the merits of a "filled-aperture" telescope (full-size mirror) versus an interferometer (widely separated smaller mirrors to increase resolving power). Photon-starved astronomers campaigned for a filled-aperture telescope, saying that it was a more sensible option for a 10- to 16-meter class telescope. They contended that the high-resolution needs of the interferometer advocates could be better served by pursuing projects with much longer baselines.

Where would this super space telescope be located? High-Earth orbit, beyond 24,000 miles, was an appealing option. Constraints imposed by low-Earth orbit, such as interference from trapped electrons in the Van Allen belts, finite orbital lifetime, frequent Earth occultations of objects, and dangers from space debris, could be avoided. However, at high-Earth orbit, the telescope's detectors would be mercilessly pelted by cosmic rays, and maintenance could be difficult.



A 16-METER TELESCOPE looks into space from its lunar base. A protective visor has been retracted on rails, which lie on both sides of the telescope.

Many agreed that the Moon would be a more attractive location for several reasons. It provides a very stable platform. Detectors could be buried as deep as 65 feet into the lunar surface to protect them from cosmic rays. Lunar gravity would allow for construction of structures larger than what would be possible in the weightless conditions in orbit. With an established lunar base the telescope would be more accessible for maintenance and upgrading as well as expansion, in the case of interferometers. And given the proper materials technology, resilient telescopes could be constructed to withstand extreme night-to-day temperature swings.

Many workshop participants were excited by the potentially rich harvest of observations a large space telescope would provide. Astronomers would be able to probe deep into space and time to the era of galaxy formation at red shifts of 2 and 3, witnessing the dynamics of young, newly formed galaxies at the same level of detail that optical telescopes show us in nearby galaxies today. Similarly, the dynamic regions around quasars could be more closely measured and scrutinized, giving us insights into their mysterious nuclei.

Investigating the distribution of stellar masses is crucial to understanding not only our Galaxy's evolution, but the evolution of other galaxies as well. A 16-meter class telescope is powerful enough to resolve stars in galaxies lying at the distance of the Virgo Cluster, about 52 million light-years away. Such resolution would provide a gold mine of information regarding the evolution of stars in different types of galaxies.

The telescope would also benefit solar system astronomy. The instrument's high resolution would complement robotic planetary missions and help provide sensitive, detailed studies of the solar system. The telescope could assess the size and shape of comet nuclei and asteroids. Features as small as ten miles across could be seen on a comet 50 million miles away. Of particular importance would be geologic and climatic studies of Mars; astronomers could discern Martian features at least 6 kilometers in diameter.

Perhaps the most compelling scientific objective discussed at the workshop was the detection of extra-solar planets. A 16-meter telescope could detect Jupiter-sized planets out to a distance of 200 light-years, a volume of space encompassing more than 100,000 stars. But Roger Angel of Steward Observatory took this goal a step further, asserting that a 16-meter telescope that has a carefully polished mirror and is cooled to 80 kel-

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vins would be capable of detecting the presence of organic life on Earth-like planets. His strategy is to look for oxygen, methane, and ozone absorption lines in the infrared. He added that within a 20-light-year radius from Earth, there are six suitable candidates for the search.

The general consensus, as expressed by Dominique Tenerelli of Lockheed Missile and Space Company, was "the workshop has demonstrated that the technology is available and we know how to build upon it." Support must now be sought from the astronomical community, scientific goals must be crystallized, and technical details ironed out. Moreover, recommendations must be made to the federal government and NASA.

Participants agreed that it is not too early to start planning this ambitious endeavor. In fact, lead time for such complex projects is normally about twenty-five years. (Planning for the *Hubble Space Telescope* began in the early 1960s.) But it is too early to pick a site for this great observatory because the driving force will be political, not astronomical. The strategy, as advised by Ed Weiler of NASA, is to develop technologies common to both lunar and high-orbit sites. A few years from now, when more information becomes available regarding NASA's space program, a decision could be made.

It is mind-boggling to consider the scientific fruit this project could bear. But until it sees first light, the second-generation space telescope will have to serve as a technological criterion into the twenty-first century. — *Shireen Gonzaga*

SPACE TELESCOPE READIED FOR LAUNCH

During October the *Hubble Space Telescope* moved one step closer to its launch on March 26, 1990. NASA enlisted the U.S. Air Force to fly the 43-foot-long, twelve-ton spacecraft across the country from Lockheed's Sunnyvale, California, plant to the Kennedy Space Center in Florida.

HST left California on the evening of October 3 and arrived in Florida the following morning. After unpacking the spacecraft, NASA engineers moved it to Kennedy's Vertical Processing Facility, where it will undergo extensive launch preparations through March 1990. "The move was flawless," said project manager Fred Wojtzlik, "and all indications are that the telescope made the trip in fine shape."

NASA engineers hope the telescope will have an effective lifetime of fifteen years.

Amateur News

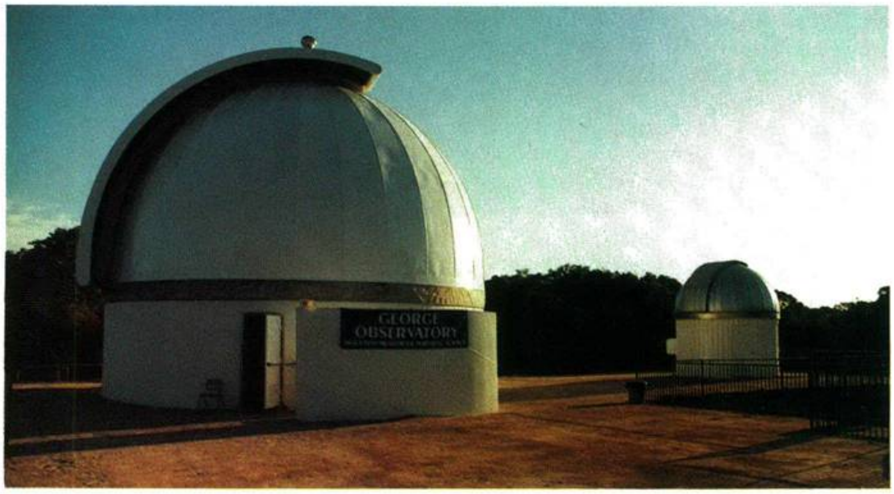
GEORGE OBSERVATORY OPENS IN TEXAS

A unique observatory opened near Houston last October. The observatory is equipped with the largest telescope available for use by amateurs in the United States. Operated by the Houston Museum of Natural Science, George Observatory contains a 36-inch Ritchey-Chretien telescope purchased from Louisiana State University in 1988. Two smaller domes contain 16-inch and 14-inch telescopes.

Located in Brazos Bend State Park about fifty miles southwest of Houston, the observatory is a cooperative venture between the Houston Museum and several organizations. "We feel it is unique in the astronomy community and can serve as a model for other cooperative relationships between museums, state parks, universities, school districts, and amateur astronomers," said Carolyn Sumners, director of astronomy at the Houston Museum. The observatory was funded by the Texas Parks and Wildlife Department, the George Foundation, and the Houston Museum. The majority of the capital investment, about $770,000, came from the George Foundation, a fund established forty years ago by the Texas philanthropists A. P. and Maimie George.

The observatory will be used purely for nonprofessional astronomy and public education. The 36-inch telescope is equipped with a spectrograph and camera, so interested persons can take high-quality sky photographs and spectrograms. Below the main dome lies a one-story learning center that seats about one hundred people for lectures, slide shows, and demonstrations not only about astronomy, but also geology, ecology, and environmental science. A heliostat perched on an upper observing deck feeds a live image of the Sun into the demonstration area. The demonstration area also contains an IBM-sponsored exhibit on Copernicus, Galileo, Newton, and other early astronomers.

George Observatory is open for public viewing on Saturdays; classes will be held on Thursdays, Fridays, and Sundays. To accommodate the maximum number of visitors, the observatory will make five Dobsonian telescopes, six Schmidt-Cassegrains, two Newtonians, two Maksutovs, and thirty-eight small refractors available for public viewing in addition to the three large telescopes. When not being used by the public, these instruments will be available for advanced astronomy viewing and research programs predominantly by Houston Museum staff and members of two local astronomical societies, the Houston Astronomical Society and the Fort Bend Astronomical Society. For further information on visiting George Observatory, contact Terrell E. Falk, Houston Museum of Natural Science, One Hermann Circle Drive, Houston, Texas 77030. ☐



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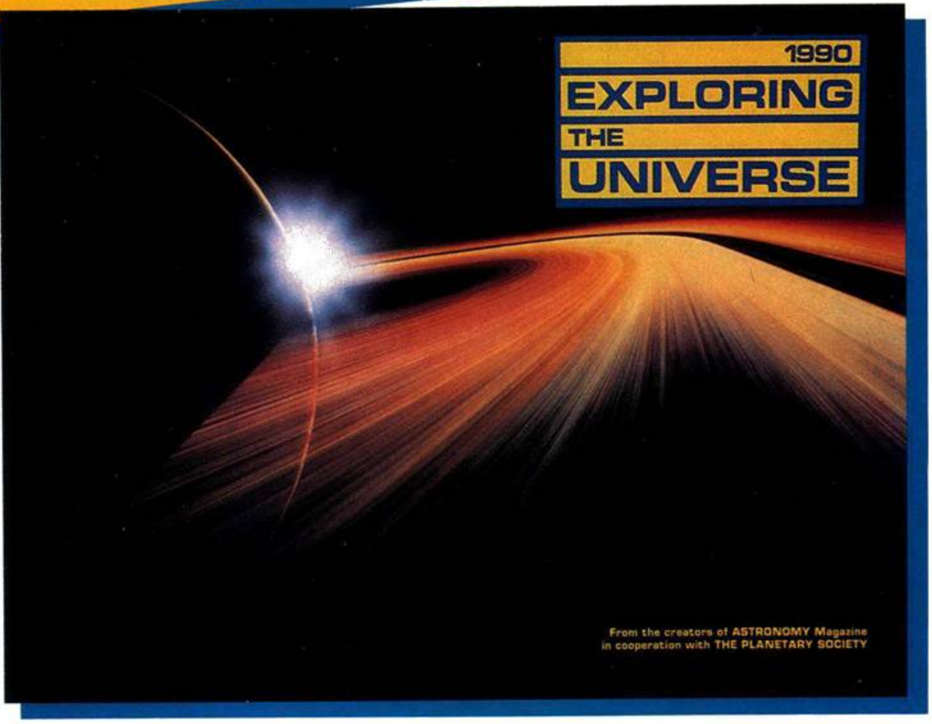
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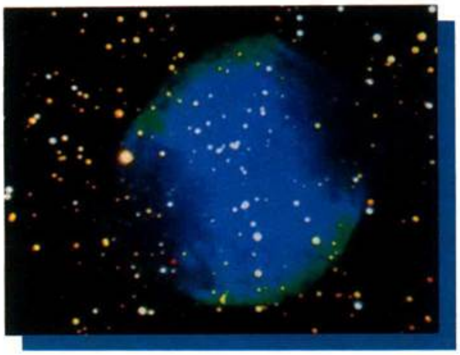

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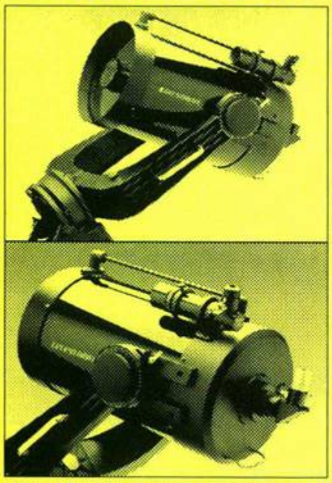

Complete 11-inch aperture, f/10 (280mmA, 2,800mmF) Schmidt-Cassegrain Telescope Tube Assembly, with StarBright optical coatings group on the optical surfaces, and a manual-positioning handle mounted on the rear cell; counterweight bar assy; widefield 8x50mm right-angle/straight-thru (convertible) Finderscope with built-in illuminated polar-alignment reticle; 2.0" mirror star diagonal, with 1.25" adapter; 30mm (93x), 1.25" barrel, multi-coated, premium-grade Plossl eyepiece; 17mm (165x), 1.25" barrel, multi-coated, premium-grade, high-power Plossl eyepiece; massive, heavy-duty Dual-Fork Astronomical Mount with oversize bearings and deeply-ribbed fork tines with chromed carrying/positioning handles; giant graduated setting circles, manual positioning controls and clutches on both axes of motion; 12 VDC digital quartz microelectronic motor-drive tracking system (for N hemisphere *only*), precision 7.5" diameter worm-drive gearing, ***and field-rechargeable battery for completely cordless operation,*** all built into "drive-base"; car-battery power-cord/plug; universal AC-adapter/battery- charger; deluxe, heavy-duty, adjustable Equatorial Wedge with micrometric adjusters for latitude and azimuth, latitude scale and bubble level; deluxe, heavy-duty, adjustable Field Tripod with positive, all-metal leg locks and 2" dia., upper leg sections for maximum rigidity, rubber-coated for vibration damping; anti-vibration footpads for tripod; Dust Covers for optical apertures; large, deluxe, extra-rugged molded Carrying Case for scope-tube/fork-mount/drive-base assembly, with die-cut foam lining and room for accessories; Instruction Manual; limited lifetime warranty. Some assembly required.

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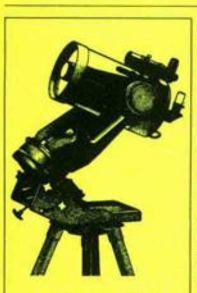

Ultima C8

Complete 8-inch aperture, f/10 (203mmA, 2,032mmF) Schmidt-Cassegrain Telescope Tube Assembly, with StarBright optical coatings group on the optical surfaces, and a manual-positioning handle mounted on the rear cell; widefield 8x50mm right-angle/straight-thru (convertible) Finderscope with built-in illuminated polar-alignment reticle; 1.25" visual accessory holder; 1.25" multi-coated prism star diagonal; 30mm (68x), 1.25" barrel, multi-coated, premium-grade Plossl eyepiece; 7mm (290x), 1.25" barrel, fully coated, premium-grade, high-power Orthoscopic eyepiece; massive, heavy-duty Dual-Fork Astronomical Mount with oversize bearings and deeply-ribbed fork tines with chromed carrying/positioning handles; giant graduated setting circles, manual positioning controls and clutches on both axes of motion; 12 VDC digital quartz microelectronic motor-drive tracking system (for N hemisphere *only*), precision 7.5" diameter worm-drive gearing, ***and field-rechargeable battery for completely cordless operation,*** all built into "drive-base"; car-battery power-cord/plug; universal AC-adapter/battery-charger; deluxe, heavy-duty, adjustable Equatorial Wedge with micrometric adjusters for latitude and azimuth, latitude scale and bubble level; deluxe, heavy-duty, adjustable Field Tripod with positive, all-metal leg locks and 2" dia., upper leg sections for maximum rigidity, rubber-coated for vibration damping; Dust Covers for optical apertures; large, deluxe, extra-rugged molded Carrying Case for scope-tube/fork-mount/drive-base assembly, with die-cut foam lining and room for accessories; Instruction Manual; limited lifetime warranty. Some assembly required.

Ultima C8, StrBrt, Wedge, Tripod (as above) ...... (List: $ 3,398) .... CALL

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PowerStar IV C8

Complete 8-inch aperture, f/10 (203mmA, 2,032mmF) Schmidt-Cassegrain Telescope Tube Assembly, with StarBright optical coatings group; DewStar lensshade; widefield 8x50mm right-angle Finderscope with built-in illuminated polar-alignment reticle; 1.25" visual accessory holder; 1.25" star diagonal; 30mm (68x), 1.25" barrel, multi-coated, premium-grade Plossl eyepiece; 7mm (290x), 1.25" barrel, fully coated, premium-grade, high-power Orthoscopic eyepiece; Dual-Fork Astronomical Mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; 12 VDC digital quartz microelectronic motor-drive tracking system (for N ***or*** S hemisphere) and precision 7.5" diameter worm-drive gearing, built into "drive-base"; DC battery-pack *(batteries* ***not*** *included);* car-battery power-cord/plug; universal AC power adapter, cord & plug; Drive Corrector Hand Control Unit, with additional controls and connectors for optional accessory electronic equipment; deluxe adjustable Equatorial Wedge with micrometric adjusters for latitude and azimuth, latitude scale, bubble level and no-tool knob set; adjustable-height Field Tripod; Dust Covers for optical apertures; extra-rugged molded Carrying Case for scope-tube/fork-mount/drive-base assembly, with die-cut foam lining and room for accessories; T-Adapter; Piggyback Mount; Instruction Manual; Product Guide and Reference Manual; limited lifetime warranty. Some assembly required.

PwrStr IV C8, StrBrt, Wedge, Tripod (as above) (List: $ 2,998) .... CALL

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Classic C8

The Classic C8 is the perfect telescope for the budget-minded buyer. Complete 8-inch aperture, f/10 (203mmA, 2,032mmF) Schmidt-Cassegrain Telescope Tube Assembly; widefield (8.0° field-of-view) 6x30mm straight-through Finderscope; 1.25" visual accessory holder; 1.25" prism star diagonal; 25mm (81x), 1.25" barrel, multi-coated, Kellner eyepiece; Dual-Fork Astronomical Mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; 110V 60 Hz AC electric motor-drive tracking system (for N hemisphere *only*) built into telescope "drive-base"; AC power cord; adjustable Equatorial Wedge; adjustable-height Field Tripod; Dust Covers for optical apertures; Instruction Manual; limited lifetime warranty. StarBright optical coatings group is optionally available at extra cost. Some assembly required.

Classic C8, Wedge, Tripod (as above) .... (List: $ 1,956) .... CALL
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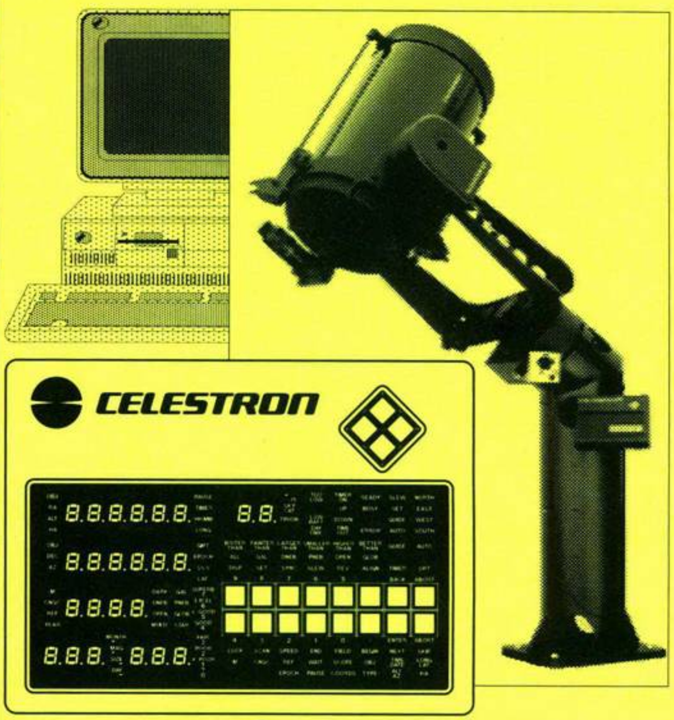

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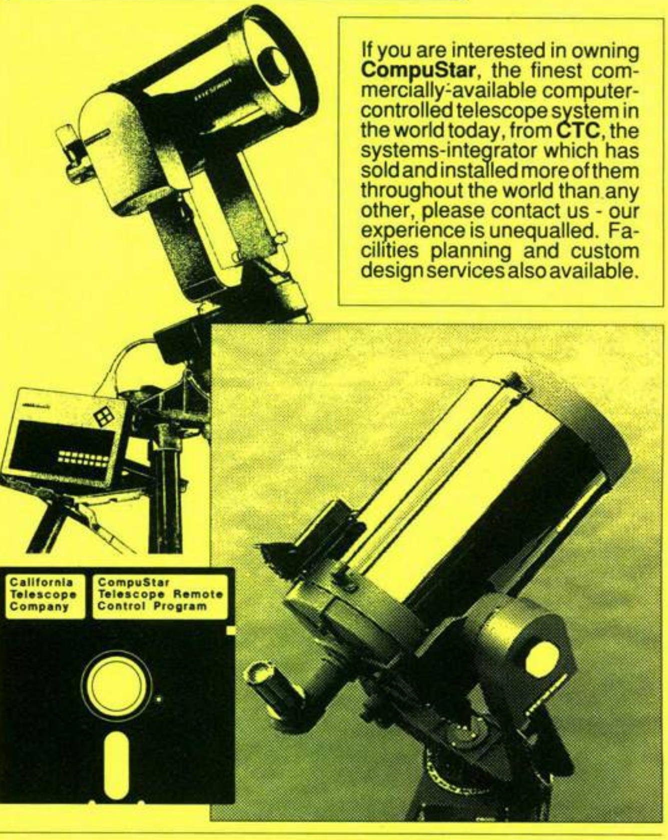

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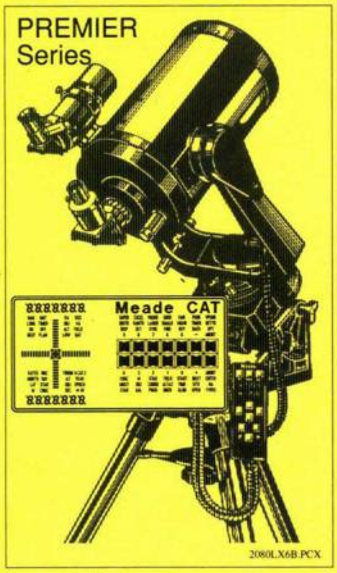

"Premier Series" Telescope Specifications					Eyepiece Magnifications			
Model	f/#	Aperture	Area	Focal Length	40mm	26mm	14mm	6.7mm
76 / 2080	6.3	8 in (203 mm)	50 in²	50 in (1,280 mm)	32.0 x	49.2 x	91.4 x	191.0 x
76 / 2120	6.3	10 in (254 mm)	78.5 in²	63 in (1,600 mm)	40.0 x	61.5 x	114.3 x	238.8 x
70 / 2080	10	8 in (203 mm)	50 in²	80 in (2,032 mm)	50.8 x	78.2 x	145.1 x	303.3 x
70 / 2120	10	10 in (254 mm)	78.5 in²	100 in (2,540 mm)	63.5 x	97.7 x	181.4 x	379.1 x

Meade's new ***Premier Series Telescopes*** consist of either an **f/10 (*Series 70*)** or an **f/6.3** (***Series 76***) Telescope Tube Assembly, of either 8" or 10" aperture, mated to their highly-computerized "LX6" Drivebase, ***and including both*** their electronic **Digital Readout System ("DRS")** and their **Computer-Aided Telescope ("CAT")** System as standard, built-in, factory-installed equipment, plus a number of other desirable accessories not normally included as standard equipment with their other models (declination motor; electric focuser; off-axis guider system [all for astrophotography]; four eyepieces; SuperWedge on 10" scopes).

Specs: Complete Schmidt-Cassegrain Telescope Tube Assembly (see table for apertures, focal lengths, focal ratios, etc.), with *Multi-Coated Optics Group* on the optical surfaces; giant 9x60mm right-angle Finderscope with built-in illuminated polar alignment reticle and quick-disconnect mounting bracket;

2.00" mirror star diagonal, with 1/10 wave multi-coated mirror and 1.25" adapter; 6.7mm, 1.25" barrel *UWA* eyepiece; 14mm, 2.00"/1.25" barrel *UWA* eyepiece; 26mm, 1.25" barrel *SP* eyepiece; 40mm, 2.00" barrel *SWA* eyepiece;

Rugged Dual-Fork Astronomical Mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; 12VDC digital quartz microelectronic motor-drive tracking system (N ***or*** S hemisphere) and ultra-precision "LX" worm-drive gearing built into telescope drive base; Power Control Panel (also built into drive base) with controls, indicators and connectors for various accessory and auxilliary electronic equipment;

Electronic Command Center hand-control unit, with complete, factory-installed Digital Readout System; complete, factory-installed Computer-Aided Telescope system; 120VAC 60Hz power adapter with 25 ft. cord; DC battery-pack *(batteries **not** included)* with 4 ft. cord; 25 ft. DC power cord with automobile cigarette-lighter plug;

Astrophotography accessories consisting of: complete Off-Axis Guider System [***T-Ring not included***], including illuminated-reticle guiding eyepiece; Electric Focuser; and Electric Declination Control (motor);

Deluxe Equatorial Wedge (heavy-duty SuperWedge on 10" aperture scopes) with micrometric adjusters for latitude and azimuth, latitude scale, bubble-level and magnetic compass; ultra-rigid adjustable-height Field Tripod; Dust Covers for optical apertures; foam-lined Carrying Case for scope-tube/fork-mount/drive-base assembly; Instruction Manual; Limited Lifetime Warranty. *Some assembly required.*

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Our Stk Number	Model No. or Key Word(s)	Description	List US$ Price	Our US$ Price
021-800	**Mod. 70 / 2080**	**8" f/10 S-C, *MCOG*, ... Std. Wedge & Tripod**	**5,998.00**	**CALL**
021-820	**Mod. 70 / 2120**	**10" f/10 S-C, *MCOG*, ... SuperWedge & Tripod**	**7,198.00**	**CALL**
021-840	**Mod. 76 / 2080**	**8" f/6.3 S-C, *MCOG*, ... Std. Wedge & Tripod**	**6,398.00**	**CALL**
021-860	**Mod. 76 / 2120**	**10" f/6.3 S-C, *MCOG*, ... SuperWedge & Tripod**	**7,598.00**	**CALL**

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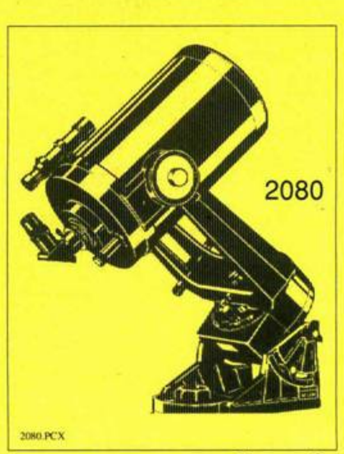
Our Stk Number	Model No. or Key Word(s)	Description	List US$ Price	Our US$ Price
309-101	AC Pwr Suply	220VAC 50/60Hz Power Supply, for LX6 Mtr Drives	29.95	CALL
305-270	Battery Pack	12VDC, 6.5 Amp-Hour Battery Pack, .. with Charger	149.95	CALL
305-272	Battery Pack	12VDC, 13.0 Amp-Hour Battery Pack, .. with Charger	199.95	CALL

2080: Complete 8-inch aperture, f/10 (203mmA, 2,032mmF) Schmidt-Cassegrain Telescope Tube Assembly; 6x30mm viewfinder; 1.25" eyepiece holder; 1.25" prism star diagonal; 25mm (81x) MA eyepiece, 1.25" barrel; Dual-Fork Astronomical Mount with graduated setting circles, manual positioning controls and clutches on both axes of motion; 120VAC 60Hz motor-drive tracking system (for N hemisphere *only*) and worm-drive gearing built into telescope drive base; AC power cord; adjustable Equatorial Wedge; adjustable-height Field Tripod; dust covers for optical apertures; instruction manual; Limited Lifetime Warranty. *Some assembly required. Multi-Coated Optics Group* optionally available.

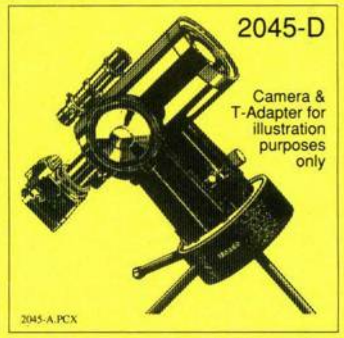
Premium Accessory Upgrade Pkg: The following *premium* accessories may be substituted: giant 9x60mm illuminated-reticle polar-alignment viewfinder; 2.00" mirror-type star diagonal, with 1/10 wave mirror and adapter for 1.25" eyepieces; *Series 4000*, 26mm (78x), 1.25" barrel *Super Plossl* eyepiece.



Model	f/#	Aperture	Area	Focal Length
2080	10	8 in (203 mm)	50 in²	80 in (2,032 mm)

Our Stk Number	Model No. or Key Word(s)	Description	List US$ Price	Our US$ Price
021-515	2080-A	8" Schmidt-Cass, ... Wedge & Tripod	1,738.00	CALL
021-517	2080-A PKG	2080-A, Accessory Pkg, ... Wedge & Tripod	2,238.00	CALL
021-516	2080-B	8" Schmidt-Cass, *MCOG*, ... Wedge & Tripod	1,858.00	CALL
021-518	2080-B PKG	2080-B, *MCOG*, Accessory Pkg, ... Wedge & Tripod	2,358.00	CALL

2045-D: Complete 4-inch aperture, f/10 (102mmA, 1,016mmF) Schmidt-Cassegrain Telescope Tube Assy with certified diffraction-limited optical system; high-transmission anti-reflection coatings on corrector plate (*HTC*); ultra-smooth anti-back-lash focuser; 5x24mm finderscope; 1.25" prism-type star-diagonal/eyepiece-holder; 25mm (41x) MA eyepiece,1.25" barrel; rugged Dual-Fork Astro Mount, with 12VDC digital-electronic tracking motor built into base and N-S hemisphere switch, graduated setting circles, manual positioning controls & clutches on both axes of motion; "tabletop tripod" legs (adjustable for latitude); dust covers; penlite battery pack (batteries ***not*** included); instructions; Limited Lifetime Warranty. *Some assembly required.*


2045-D
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2045-A.PCX

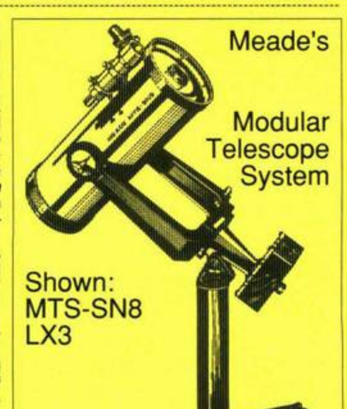
Model	f/#	Aperture	Area	Focal Length
2045-D	10	4 in (101.6 mm)	12.5 in²	40 in (1,016 mm)

Our Stk Number	Model No. or Key Word(s)	Description	List US$ Price	Our US$ Price
021-220	2045-D	4" Schmidt-Cass, *HTC*	1,300.00	CALL
029-740	Carry Case	Carrying Case, ... for 2045	132.00	CALL
021-222	Combo	4" Schmidt-Cass, *HTC*, ... and Carrying Case	1432.00	CALL
026-415	Wedge & Tri	Wedge & Tripod Combination, ... for 2045	380.00	CALL

MTS-SN: Complete 6" aperture f/5, or 8" aperture f/4, Schmidt-Newtonian Telescope Tube Assy with certified diffraction-limited optical system; ultra-smooth 2" helicoid focuser, with 1.25" adapter; 25mm (30x [SN6] or 32.5x [SN8]) MA eyepiece,1.25" barrel; rugged Dual-Fork Equatorial Astronomical Mount, with graduated setting circles, latitude adjustment and latitude scale; Pipe-Pier Stand with quick-mount tri-legs; Mod. 788, 120VAC 60Hz (N hemisphere *only*), motor-drive tracking system (***optional on SN6***, standard on SN8); dust covers; Instruction Manual; Limited Lifetime Warranty. *Some assembly required.*

Optionally available: *MCOG* optical coatings group on optical surfaces; declination manual positioning control; ***SN8 only:*** 12VDC "LX3" high-precision motor-drive system (N hemisphere *only*), etc.

Note: These Schmidt-Newtonians are primarily intended to be low-power, widefield instruments. As such, they do not need, and are not equipped with, finderscopes nor high-power eyepieces. If you intend to use them for high-power, narrow-field work, you will need additional equipment.



Model	f/#	Aperture	Area	Focal Length
SN 6	5	6 in (152.4 mm)	28.3 in²	30 in (762 mm)
SN 8	4	8 in (203 mm)	50 in²	32 in (813 mm)

Our Stk Number	Model No. or Key Word(s)	Description	List US$ Price	Our US$ Price
023-122	MTS-SN 6	6"A, f/5 S/N, ... with MTS-Mount & Pedestal	1,050.00	CALL
023-123	MTS*SN 6	6"A, f/5 S/N, *MCOG*, .. with MTS-Mount & Pedestal	1,130.00	CALL
023-124	MTS-SN6-788	6"A, f/5 S/N, ... MTS-Mnt/Ped, 788 MtrDrv	1,200.00	CALL
023-126	MTS*SN6-788	6"A, f/5 S/N, *MCOG*, ... MTS-Mnt/Ped, 788 MtrDrv	1,280.00	CALL
023-132	MTS-SN8-788	8"A, f/4 S/N, ... MTS-Mnt/Ped, 788 MtrDrv	1,500.00	CALL
023-133	MTS*SN8-788	8"A, f/4 S/N, *MCOG*, ... MTS-Mnt/Ped, 788 MtrDrv	1,590.00	CALL
023-134	MTS-SN8-LX3	8"A, f/4 S/N, ... MTS-Mnt/Ped, LX3 MtrDrv (does ***not*** include Mod. 36 Hand Control Unit)	1,800.00	CALL
023-136	MTS*SN8-LX3	8"A, f/4 S/N, *MCOG*, ... MTS-Mnt/Ped, LX3 MtrDrv (does ***not*** include Mod. 36 Hand Control Unit)	1,890.00	CALL

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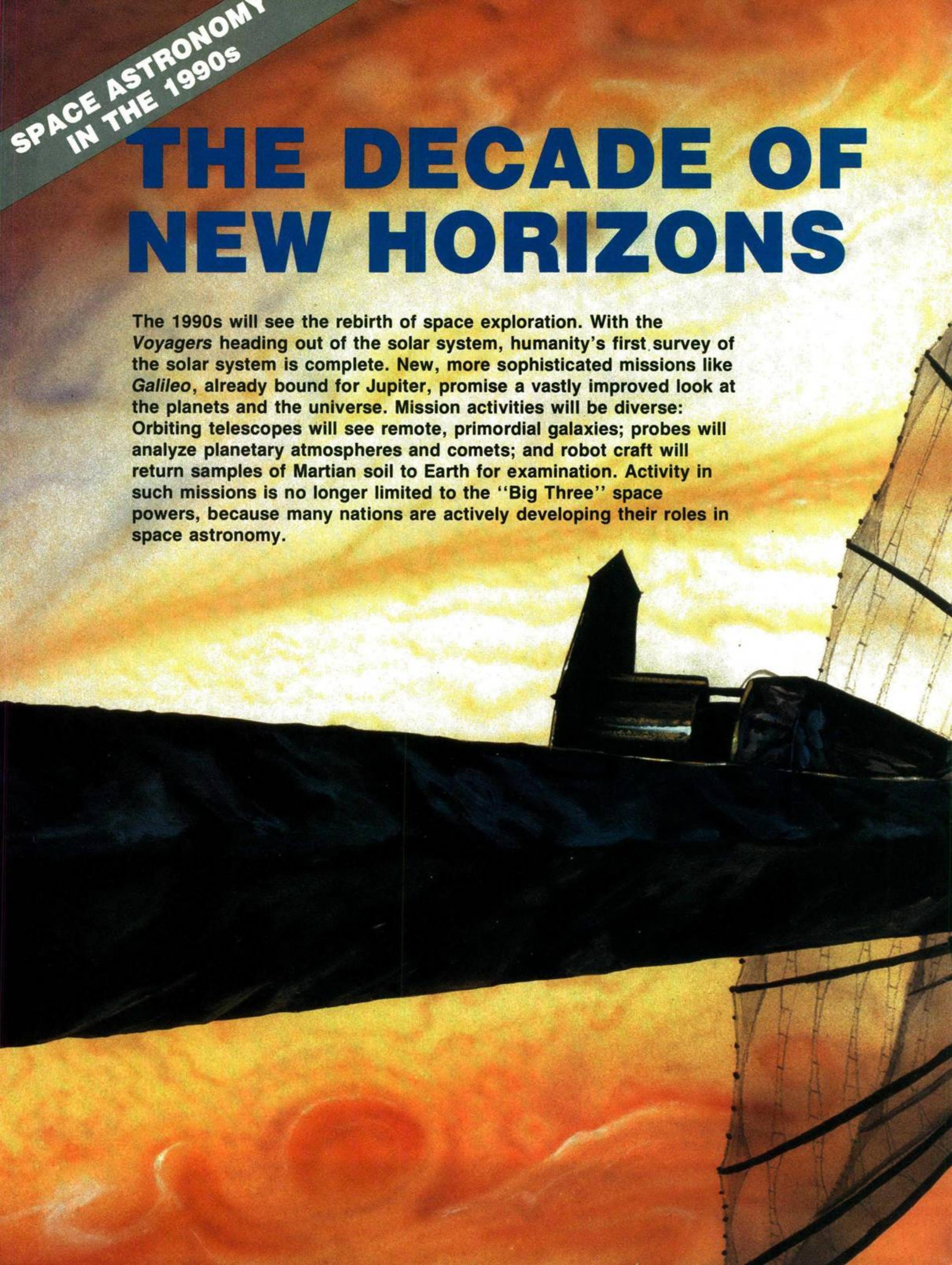
SPACE ASTRONOMY IN THE 1990s

THE DECADE OF NEW HORIZONS

The 1990s will see the rebirth of space exploration. With the *Voyagers* heading out of the solar system, humanity's first survey of the solar system is complete. New, more sophisticated missions like *Galileo*, already bound for Jupiter, promise a vastly improved look at the planets and the universe. Mission activities will be diverse: Orbiting telescopes will see remote, primordial galaxies; probes will analyze planetary atmospheres and comets; and robot craft will return samples of Martian soil to Earth for examination. Activity in such missions is no longer limited to the "Big Three" space powers, because many nations are actively developing their roles in space astronomy.



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SPACE ASTRONOMY IN THE 1990s

A NEW ERA IN SPACE

A bright future lies ahead for space exploration as a growing number of nations cooperates to better understand the universe.

by David J. Eicher

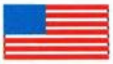
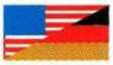
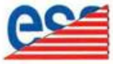
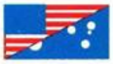
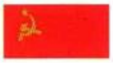
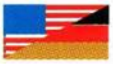
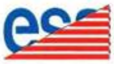
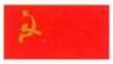
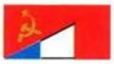
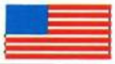
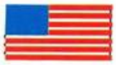
With a collective sigh of relief, the world feels good about space again. In the wake of a decade of funding cutbacks and canceled programs, the space programs of several key countries seem to be undergoing a renaissance. An impressive program of missions encompassing planetary exploration, astrophysics, and Earth science projects are now being planned. The majority of space missions planned for the 1990s are cooperative missions involving at least two countries. (Most involve in some way at least one of the "Big Three": the United States, the Soviet Union, and the European Space Agency.) The next decade will open a new era in space exploration, one that many scientists hope is only the start of better things for years to come.

In the minds of scientists, it's high time to turn a page in the book of space exploration. Probes planned and built in the 1960s and launched in the 1970s — the Pioneers and Voyagers — have completed their flybys and are now drifting out of the solar system. Technological advances made since the 1960s promise better results from missions carrying more sophisticated instruments. Scientists are anxious to carry out "round two" of solar system exploration and hope to solve many questions raised by earlier spacecraft missions. Additionally, vast amounts of data remain to be collected in many areas of astrophysics and Earth observation.

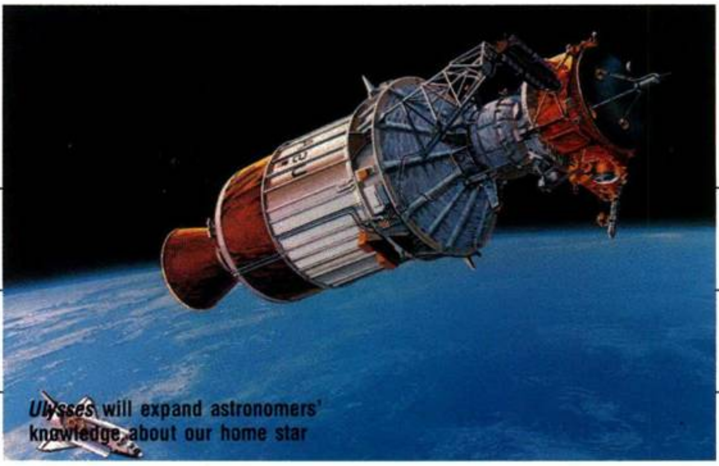
Cooperation is the key word for the new era in space. Of the fifty-three major missions to be launched sometime in the 1990s, twenty-one are joint missions involving two or more countries in primary roles. Nearly all fifty-three missions carry experiments or use parts from nations other than the one launching the spacecraft. Such international cooperation was relatively rare a decade ago; it developed at the mission planning offices of the world's space agencies only during the past several years. Such cooperation is a matter of survival for many scientists' projects. The types of complex, high-tech missions planned by space agencies for the 1990s will not come cheap, and the greater the number of players, the more affordable a mission is for any single nation. Cooperation also allows scientists from different countries to pool their expertise to ensure the greatest chance of success.

The big players in space exploration are the United States, the Soviet Union, and the European Space Agency (ESA). (In operation since 1980, ESA is a consortium made up of Austria, Belgium, Denmark, West Germany, Finland, France, Ireland, Italy, the Nether-

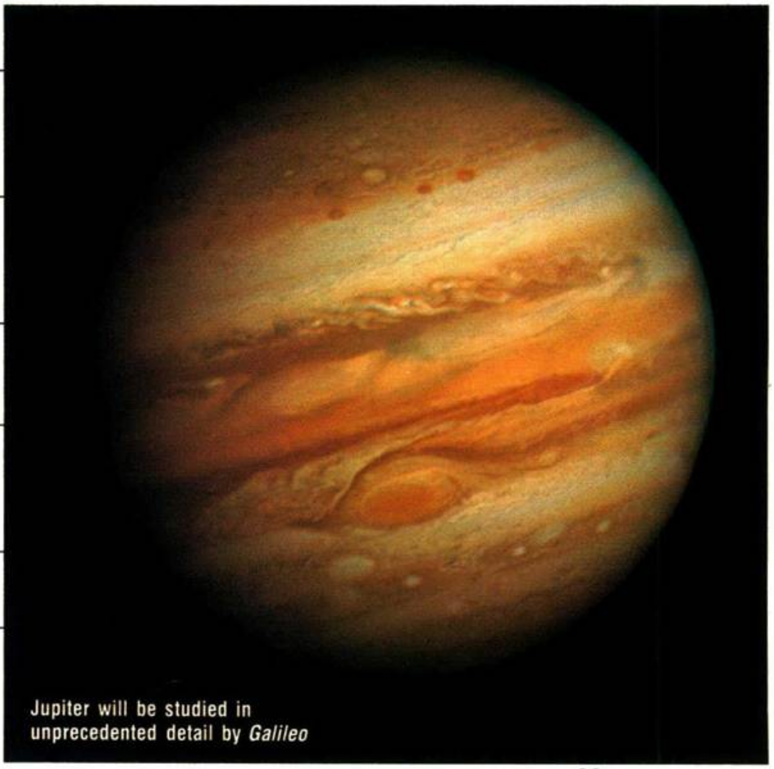
Solar System Missions

Launch Date	Mission Name	Nation
April 28, 1989	**Magellan**	
October 18, 1989	**Galileo**	
October 5, 1990	**Ulysses**	
September 1992	**Mars Observer**	
1994	**Colomb/Mars 1994**	
1995	**Comet Rendezvous and Asteriod Flyby** (CRAF)	
1996	**Cassini/Huygens**	
1996	**Mars Rover Mission**	
1996	**Vesta**	
May 1998	**Solar Probe**	
December 1998	**Mars Sample Return Mission**	

Description
In August 1990 the *Magellan* spacecraft will assume a polar orbit about Venus, beginning a 243-day mapping mission that will image the planet down to 1-kilometer resolution.
Galileo consists of an orbiter and a probe: on arrival at Jupiter in 1996 the orbiter will study Jupiter's magnetosphere and satellites from above while the probe descends into the Jovian cloud tops.
Ulysses will study the never-before-observed north and south poles of the Sun, when it passes 214 million miles below the Sun's south pole in 1994.
The *Mars Observer* spacecraft will reach Mars in August 1993 and use a combination of seven instruments to investigate Martian mineralogy, map Martian topography, and study the behavior of the planet's atmosphere.
The Soviets plan to launch a Mars orbiter that will arrive in 1995. Either a single or dual spacecraft will image the planet at 1-meter resolution, drop balloons to sample the atmosphere, and also drop a probe to the surface.
CRAF will encounter asteroid Hamburga in 1998; two years later it will rendezvous with the periodic Comet Kopff near aphelion and then study the comet for three years as the comet moves toward the Sun and forms a tail.
The *Cassini* spacecraft will begin a detailed, four-year study of the Saturnian system when it reaches the ringed planet in 2002. The spacecraft will drop a probe called *Huygens* into the atmosphere of Titan.
Soviet plans include a 1996 mission that will land a roving vehicle on the surface of Mars to explore and sample the Martian surface. The rover will have an effective lifetime of five years.
Vesta will encounter between ten and twenty asteroids and a minimum of two comets over a period of seven years. At each asteroid flyby the spacecraft will launch two penetrators that will return data on surface composition.
Solar Probe will be the first spacecraft sent within 30 million miles of the Sun; it will sample fields and particles in the solar vicinity.
NASA plans to take advantage of a 1998 launch window to send an array of instruments that would function together to return Martian samples to Earth. Rovers would be used to gather surface material and transport it to return vehicles.



Ulysses will expand astronomers' knowledge about our home star



Jupiter will be studied in unprecedented detail by *Galileo* lands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.) However, the new spirit of cooperation has allowed other nations, such as Japan and East Germany, to move into the picture, and in some cases ESA members act through their own space agencies, independent of ESA.

In 1993 the U.S. *Mars Observer* spacecraft will begin orbiting Mars, studying the chemical makeup of the Martian surface, following the progress of dust clouds, and mapping the Martian magnetic field. No less than six countries — the United States, West Germany, Austria, France, the Soviet Union, and the United Kingdom — are involved in the project. Such cooperation exists in other areas of space astronomy. In February NASA will launch a Delta-II rocket carrying the West German x-ray satellite *Roentgen;* scientists from both countries will be involved with the project at every step. Cooperative Earth science missions seem especially appropriate in an era when inhabitants of Earth are becoming increasingly concerned about humanity's use of the environment. A retinue of satellites will be launched over the coming decade to study the planet's oceans, forests, and magnetic fields in far greater detail than previous missions. Apart from the United States, the USSR, and ESA, active co-participants in Earth science missions include Canada, West Germany, France, and Japan.

The Solar System: Round Two

One of the great aims of space missions in the 1990s is to initiate and carry out "round two" of solar system exploration. The first round consisted of the Apollo Moon program, the *Voyager* Grand Tour, the *Viking* Mars landers, the many U.S. and Soviet craft sent to Venus, and numerous smaller scale missions. These programs gave the world a close-up view of previously unexplored bodies in the solar system. The new round of solar system exploration will target specific worlds for missions that will gather more extensive and much higher quality data on planetary chemistry, geology, atmospheres, and magnetospheres.

The United States will sponsor fourteen solar system missions. Science goals for the missions include an emphasis on moons and planetary features not yet explored and sampling material from regions previously unexplored. Launched on April 28, 1989, *Magellan* will arrive at Venus in August 1990 and will spend eight months mapping the planet's surface with high-precision radar down to 1-kilometer resolution. *Galileo* will arrive at and orbit about Jupiter in December 1995, exploring the planet with apricular interest in the Galilean satellites, and will drop a probe into Jupiter's atmosphere to sample Jovian cloud chemistry.

The *Comet Rendezvous and Asteroid Flyby* mission, launched in 1995, will pass close by the asteroid Hamburga in 1998 and will rendezvous with periodic Comet Kopff in 2001. The craft will carry a hard-landing probe that will penetrate the comet's nucleus and transmit data about its composition to *CRAF* and then back to Earth.

The main objective of the Soviet Union's planetary exploration program is to study Mars. *Columb/Mars 1994* will arrive at the Red Planet in 1995 and photograph the planet with a limiting resolution of 1 meter. The spacecraft will also drop balloons to sample the Martian atmosphere and drop a probe to the Martian surface to conduct surface chemistry experiments. The Soviets are also planning a 1996 *Mars Rover Mission* that will land a roving vehicle on the surface of Mars.

Launch Date	Mission Name	Nation
December 1998	**Mars Sample Return Mission**	☭
2001	**Rosetta Comet Nucleus Sample Return Mission** (CNSR)	esa
?	**Lunar Observer**	🇺🇸

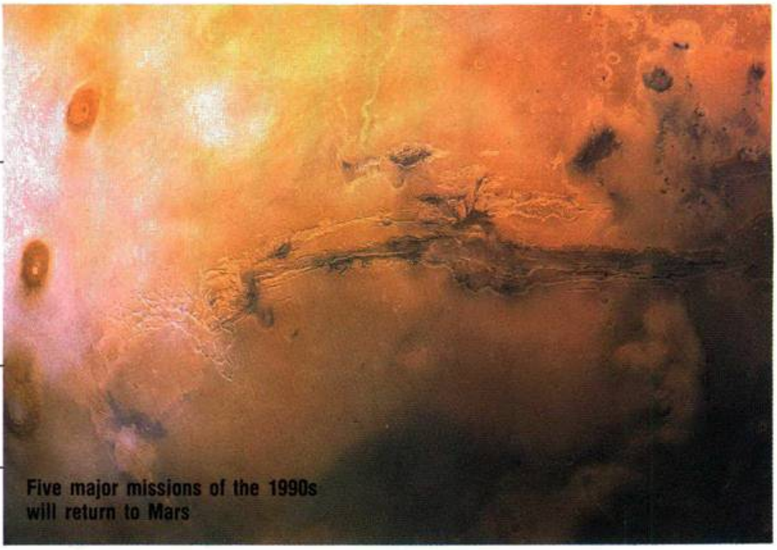
Launch Date	Mission Name	Nation
November 1989	**Cosmic Background Explorer** (COBE)	🇺🇸
February 1990	**Roentgen Satellite** (ROSAT)	🇩🇪 / 🇺🇸
March 26, 1990	**Hubble Space Telescope** (HST)	🇺🇸 / esa
June 4, 1990	**Gamma Ray Observatory** (GRO)	🇺🇸 / 🇩🇪
April 26, 1990	**Astro-1 Spacelab Mission**	🇺🇸
1990?	**Gamma-I Project**	☭ / 🇫🇷
1990?	**Granat Orbiting Observatory**	☭ / 🇫🇷
August 1991	**Extreme Ultraviolet Explorer** (EUVE)	🇺🇸
1991?	**Project Radioastron**	☭
April 1992	**Astro-2 Spacelab Mission**	🇺🇸
September 1992	**Orbiting and Retrievable Far and Extreme Ultraviolet Spectrometer** (ORFEUS)	🇩🇪 / 🇺🇸

Description

The Soviets are also planning a Mars mission that would carry samples of the Red Planet to Earth. A possibility exists that both countries will cooperate in one mission, but it is most likely that each will send their own spacecraft.

Although it won't be launched until 2001, construction of the European Space Agency's *Rosetta* spacecraft will occur over the next decade. The craft will rendezvous with a comet sometime between 2001 and 2004 and will carry a penetrator probe that will extract core and volatile samples from the comet's nucleus and coma. Once collected, the samples will be carried within the spacecraft as it returns to Earth.

If the *Mars Observer* spacecraft is successful, *Lunar Observer* will be launched to study the Moon in a global context so that local results from the Apollo program can be better understood.



Five major missions of the 1990s will return to Mars

Description

Last November the *Cosmic Background Explorer* satellite began a year-long program of investigating fundamental questions of cosmology.

An ambitious satellite project designed for a five-year lifetime, *Roentgen* will use four instruments to measure x-rays from stars, galactic supernova remnants, active and peculiar galaxies, and galaxy clusters.

The first large optical telescope placed in space, the *Hubble Space Telescope* will likely resolve questions in astrophysics, such as the distances to galaxies and whether the universe is open or closed.

The *Gamma Ray Observatory* will probe gamma-ray emitting objects in our Galaxy and beyond, with an emphasis on neutron stars and black holes.

Scheduled for launch aboard Space Shuttle flight STS-35, the *Astro-1* payload is an experiment package consisting of four instruments: three ultraviolet telescopes and an x-ray telescope.

The telescope aboard the Soviet *Gamma-I* observatory will observe gamma-ray emitters, such as the center of the Galaxy, and attempt to correlate many known gamma-ray sources in the Galaxy with optical counterparts.

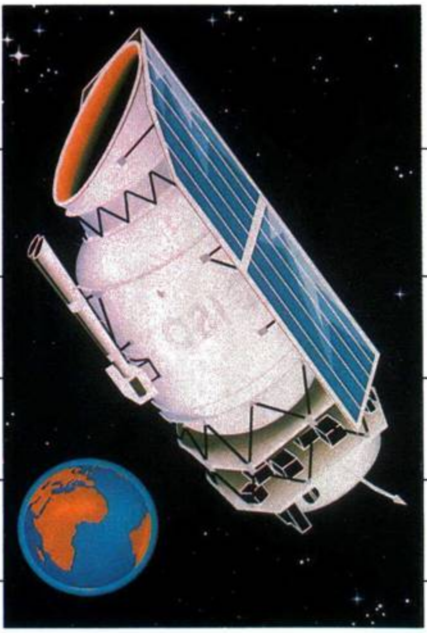
Granat is a multipurpose observatory that will observe high-energy objects such as x-ray pulsars, hot gas in galaxy clusters, gamma-ray bursters, and energetic regions surrounding black holes.

The *Extreme Ultraviolet Explorer* will investigate stellar, galactic, and extragalactic objects in ultraviolet light.

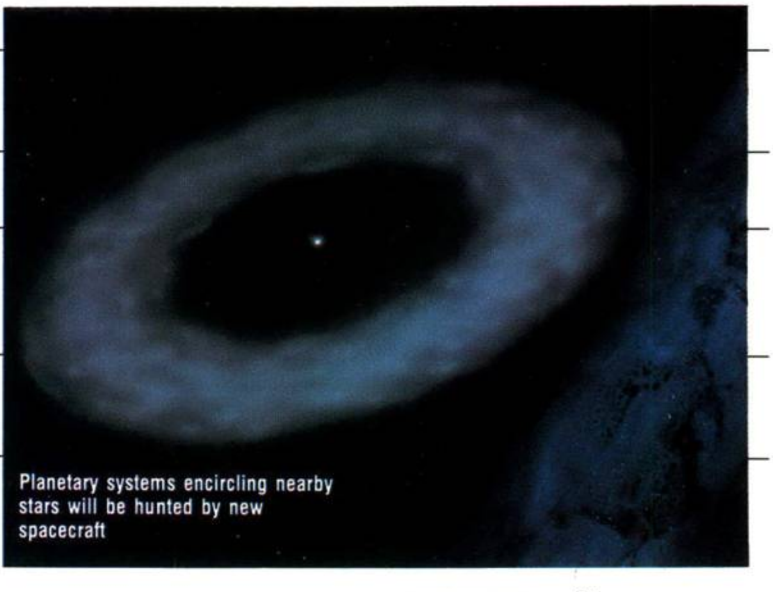
Between 1991 and 2005, *Project Radioastron* will place two small radio telescopes and a 10-meter radio telescope and antenna system into orbit. The combination will return extremely high resolution images to Earth.

Like its forerunner *Astro-1,* the *Astro-2* payload will fly aboard the space shuttle (STS-54) and be deployed for a ten-day mission of ultraviolet and x-ray astronomy.

Designed to be deployed from the space shuttle, *ORFEUS* is a 2-meter ultraviolet telescope that will separate from the shuttle by about six miles and then investigate objects in the far and extreme ultraviolet.



The European *Infrared Space Observatory* will study a wide range of objects



Planetary systems encircling nearby stars will be hunted by new spacecraft

The rover will explore the Martian surface and conduct soil analysis experiments and geological mapping for a five-year period. In 1998 the Soviet Union may launch a mission to Mars that would return samples to Earth.

The European Space Agency is planning the *Ulysses* mission, a spacecraft that will journey high above and below the Sun's poles to provide accurate data about the solar wind. The project is a joint undertaking between ESA and the United States. Another such cooperative venture is *Cassini,* which will arrive at Saturn in 2002 after a six-year journey. *Cassini* will investigate the ringed planet's internal structure and its moon Titan. *Cassini* will drop a probe called *Huygens* that will sample and analyze Titan's atmosphere and surface. Probably the most ambitious ESA mission will be *Rosetta,* a comet nucleus sample return mission scheduled for launch in 2001. *Rosetta* will travel to a comet, extract samples, and return by 2009. ESA also wants to salvage its *Giotto* spacecraft, damaged in its encounter with Halley's Comet in 1986. ESA hopes to redirect the craft toward another comet by the mid-1990s.

Stars, Galaxies, and the Universe

The core of the U.S. missions in astrophysics is the Great Observatories program. These four orbiting observatories span the wavelength range: infrared, optical, x-ray, and gamma ray. A joint project of the United States and ESA, the *Hubble Space Telescope* will be launched in March 1990. This mission will place a large astronomical telescope into orbit for the first time, yielding unprecedented images of all types of objects. Observing time on the *HST* will be used for planetary, astrophysical, and cosmological investigations that cannot be done from the ground. *HST* will resolve the centers of distant galaxies, providing information on black holes; provide the first picture of the Pluto-Charon system; search for planets orbiting nearby stars; resolve the interiors of globular star clusters; and help determine the distance scale of the universe.

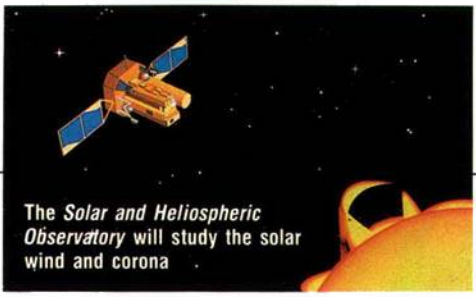
The next Great Observatory is the *Gamma Ray Observatory,* scheduled for launch on June 4, 1990. Five countries collaborated on *GRO,* which is expected to shed new light on black holes, neutron stars, and high-energy galaxies. The *Advanced X-Ray Astrophysics Facility,* slated for a 1996 launch, will provide a hundredfold increase in resolution over previous satellites. The last of the Great Observatories, the *Space Infrared Telescope Facility,* will be launched in 1998 and will search for brown dwarfs, record images of stars in the earliest stages of formation, discover distant, infrared-emitting galaxies, and image possible planetary disks around nearby stars.

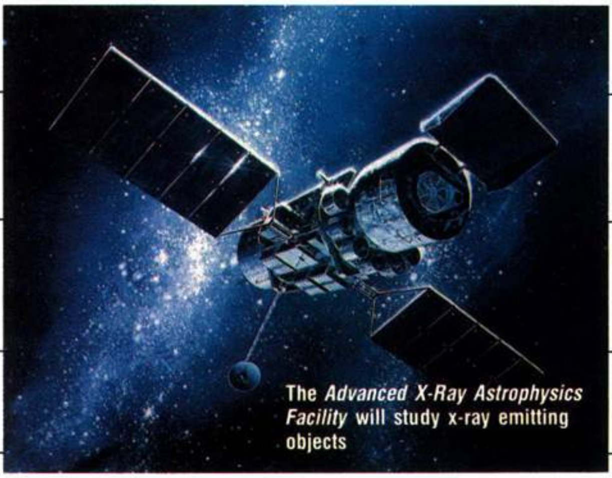
The Soviet Union will launch its *Gamma-I Project* in 1990. *Gamma-I* will undertake to correlate many known gamma-ray sources with optical counterparts, yielding a better understanding of what types of objects emit gamma rays. Slated for launch in the same year, the *Granat Orbiting Observatory* is a high-energy observatory that will search for clues about the formation and behavior of black holes, study the distribution and energy output of hot gas in galaxy clusters, and discover gamma-ray bursters. Sometime during the next decade, *Project Radioastron* will place into orbit three radio telescopes that will return extremely high-resolution images of galaxies and other radio emitters to Earth.

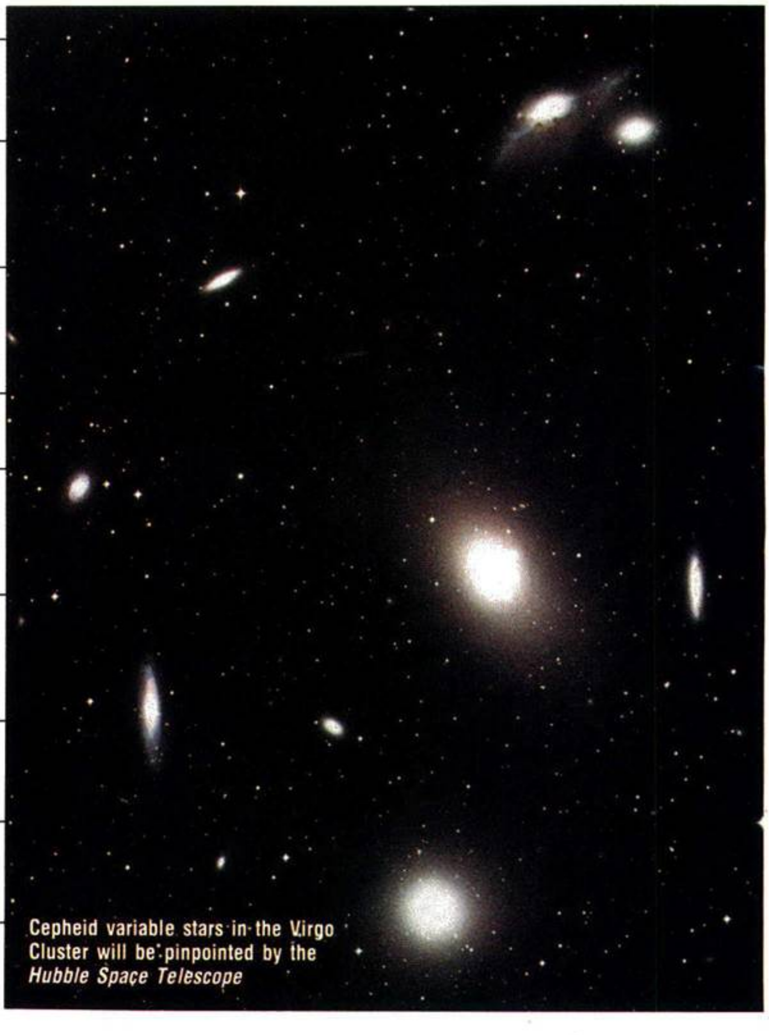
ESA's astrophysics missions include the *Infrared Space Observatory,* a satellite with a four-instrument pay-

Launch Date	Mission Name	Nation
September 1992	**Shuttle High Energy Astrophysics Laboratory** (SHEAL-2)	🇺🇸
February 1993	**Gravity Probe B** (GP-B1)	🇺🇸
May 1993	**Infared Space Observatory** (ISO)	esa
December 1993	**Submillimeter Wave Astronomy Satellite**	🇺🇸
1993?	**Spektr-Roentgen-Gamma Project**	☭ ★
March 1995	**Solar and Heliospheric Observatory** (SOHO)	esa 🇺🇸
1996	**Advanced X-Ray Astrophysics Facility** (AXAF)	🇺🇸
1998	**Space Infrared Telescope Facility** (SIRTF)	🇺🇸
1998	**High-Throughput X-Ray Spectroscopy Mission** (XMM)	esa
?	**Project Aelita**	☭ 🇮🇹
?	**Coronas Project**	☭ 🇵🇱
?	**Gamma-Ray Astronomy with Spectroscopy and Positioning Mission** (GRASP)	esa
?	**Lyman Observatory**	esa 🇺🇸
?	**Neutron Project**	☭ 🇩🇪
?	**Orbiting Solar Laboratory**	🇺🇸 🇩🇪
?	**Submillimeter Spectroscopy Mission** (FIRST)	esa

Description
An experiment package designed for shuttle deployment, *SHEAL-2* consists of two x-ray detectors: a Diffuse X-Ray Spectrometer and a Broad-Band X-Ray Telescope.
Gravity Probe B will fly aboard the space shuttle and test Einstein's general theory of relativity. The spacecraft will carry four gyroscopes above the poles of Earth to detect the curvature of space around our planet.
ISO will carry a polarimeter, a photopolarimeter, and two spectrometers. The instruments will study the atmospheres of the gas giant planets and gas-to-dust ratios in comets, protostars, and the interstellar medium.
NASA's *Submillimeter Wave Astronomy Satellite* will study starbirth by recording the abundances of water, isotopic oxygen, molecular oxygen, atomic carbon, and isotopic carbon in molecular clouds in the Galaxy.
The joint effort of eighteen countries, the *Spektr-Roentgen-Gamma Project* will send an observatory into orbit to study hot interstellar gas, supernova remnants, neutron stars, black holes, and x-ray galaxies.
SOHO will investigate the physical processes that form and heat the solar corona, give rise to the solar wind, and generate energy in the Sun's interior.
The *Advanced X-Ray Astrophysics Facility* will provide a hundredfold increase in resolution over previous x-ray satellites. *AXAF* will study a wide range of x-ray emitting objects.
The *Space Infrared Telescope Facility* will study the formation of stars, galaxies, and planets, search for comets in the outer reaches of the solar system, and search for brown dwarfs.
The European Space Agency's *XMM* satellite is designed to study high-energy phenomena such as the large scale structure of hot matter in the universe and the physical characteristics of white dwarf stars and black holes.
Project Aelita is a submillimeter-wavelength observatory with a 1-meter telescope that will study starbirth and other astrophysical phenomena like concentrations of dust in galaxies and molecular clouds.
The *Coronas Project* is a Soviet satellite designed to study the Sun's corona and chromosphere during the peak of solar activity.
The orbiting observatory *GRASP* will carry a range of sensitive instruments including a cooled Germanium Spectrometer and Cesium-Iodide Imager, both created for high-precision sampling of high-energy particles.
Lyman is a high-resolution ultraviolet spectroscopy mission to be launched sometime before 2000 on an Ariane-4 rocket. The European spacecraft will examine dynamics of the Milky Way's halo and the photochemistry of comets.
The *Neutron Project* consists of a Soviet satellite that will study the Sun's chromosphere, sunspots, and other solar phenomena during periods of low solar activity.
The *Orbiting Solar Laboratory* will carry a 1-meter telescope and two smaller telescopes with which astronomers will study the Sun's interior and atmosphere.
FIRST is designed to explore the physics of star formation, conduct cosmological studies, and examine protostellar clouds in the interstellar medium by means of submillimeter spectroscopy.


The *Solar and Heliospheric Observatory* will study the solar wind and corona


The *Advanced X-Ray Astrophysics Facility* will study x-ray emitting objects


Cepheid variable stars in the Virgo Cluster will be pinpointed by the *Hubble Space Telescope*

load that will observe heat radiation from the gas giant planets, measure gas-to-dust ratios in comets, and record background infrared emission from the interstellar medium. The *Solar and Heliospheric Observatory* is a joint project with NASA that will focus on the Sun's corona and carry an array of twelve instruments. ESA's *Lyman Observatory* may be launched before 2000 and will use ultraviolet spectroscopy to investigate the dynamics of the Milky Way, stellar winds from hot stars, and the photochemistry of comets.

Getting to Know Planet Earth

Concern for our own blue planet has risen along with public awareness of the sensitive balance between Earth's atmosphere and its possible destruction by human pollution. NASA will undertake an aggressive program of Earth science missions in the 1990s.

The NASA-launched *Upper Atmosphere Research Satellite,* scheduled for launch in October 1991, will conduct the first global measurements of the chemistry, dynamics, and energetics of Earth's atmosphere. Scientists expect this to add significantly to what we know about the behavior of Earth's atmosphere. The satellite is a collaborative project of the United States, Canada, France, and the United Kingdom. The shuttle-launched *Space Radar Laboratory* will conduct a radar survey of Earth with an interest in mapping changing patterns of botany, geology, hydrology, and oceanography. The satellite will also measure the level of carbon dioxide in Earth's atmosphere, a key indicator for tracking long-term atmospheric warming trends. NASA also plans to launch the *Wind* and *Polar* satellites, which will carry payloads to determine how the solar wind interacts with Earth.

The Soviets are planning two major Earth science missions. Scheduled for launch in 1993, *Interball* is a spacecraft carrying experiments from eighteen countries that will study the physical mechanisms of the solar wind and how these mechanisms change as the wind encounters Earth. *Regatta* will be launched in 1996 and will consist of a series of satellites that will also study effects of the solar wind on Earth's atmosphere.

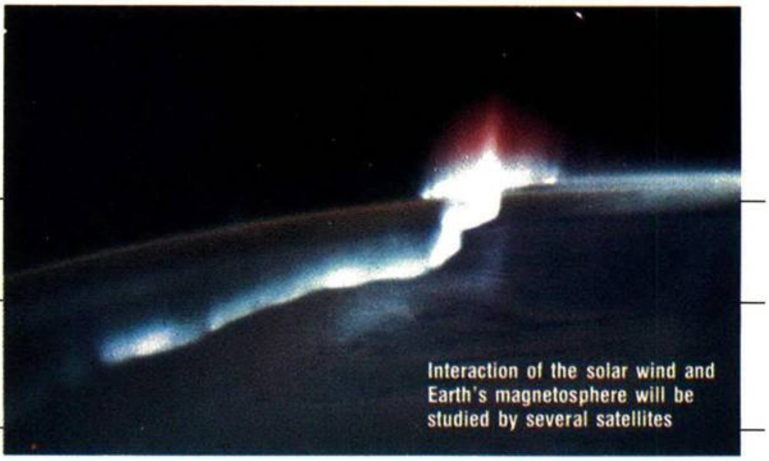
ESA has only two primary missions scheduled, both in cooperation with NASA. The *Cluster Mission* will be launched in December 1995 and will study properties of plasma states in Earth's magnetosphere. Sometime in 1996, NASA, ESA, and the Japanese Space Agency will launch the *Earth Observing System,* a group of four platforms fitted with instruments to study a wide variety of changing effects on Earth's surface and in its oceans. Additionally, ESA will take part in the Soviet *Interball* mission.

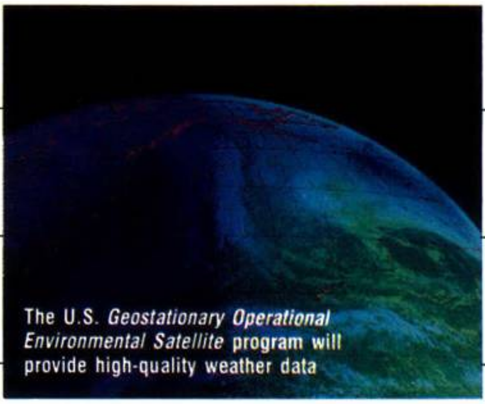
Over the coming decade, the space missions launched by the growing number of participants in space exploration and science will tackle an astonishing set of questions. These missions will take us into a new era of understanding the universe and our place in it. By returning to the planets, we may see the story of our Sun's neighborhood unfold before our eyes. By peering deep into space with the *Hubble Space Telescope,* we may answer questions that have haunted astrophysicists for decades: How large is the universe? How did galaxies originally form and how do they evolve? Will the universe keep expanding forever or collapse on itself? And by sending up sophisticated craft to look back on ourselves, we may educate humanity about the fragile balance of life on Earth and the steps that may be necessary to take better care of our home planet. ☐

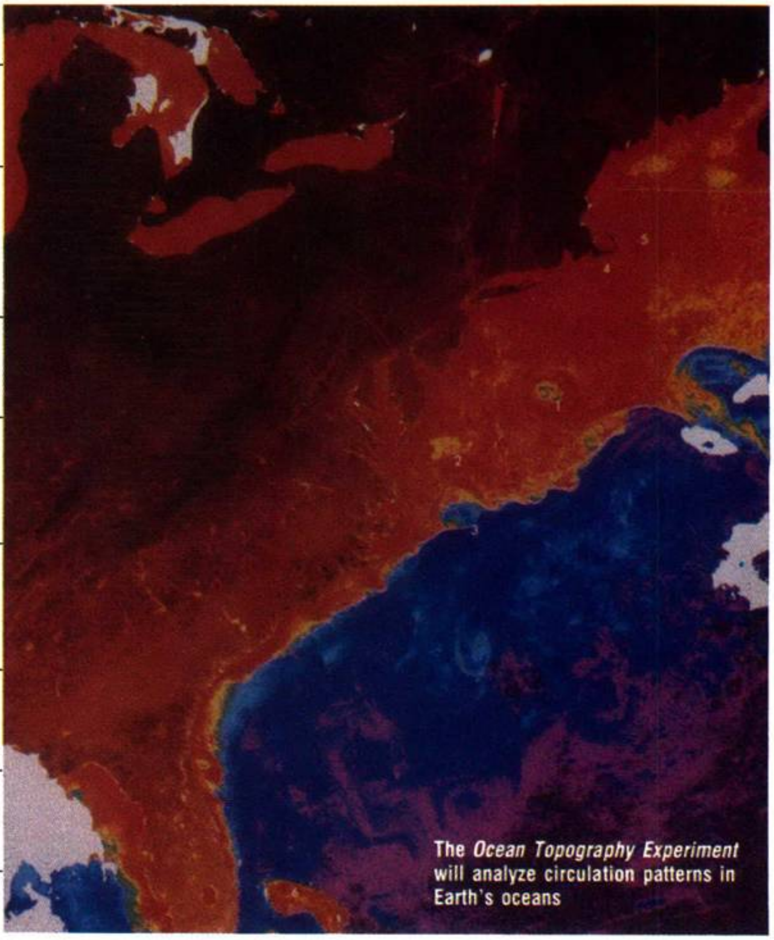
Earth Science Missions

Launch Date	Mission Name	Nation
October 1990	**Geostationary Operational Environmental Satellite** (GOES-I)	🇺🇸
March 1991	**Atmospheric Laboratory for Applications and Science** (Atlas 1)	🇺🇸🇩🇪
October 1991	**Upper Atmosphere Research Satellite** (UARS)	🇺🇸🇨🇦
June 1992	**Ocean Topography Experiment** (TOPEX/POSEIDON)	🇺🇸🇫🇷
June 1992	**Space Radar Laboratory** (SRL-1)	🇺🇸
July 1992	**Geotail Mission**	🇯🇵🇺🇸
December 1992	**Wind Mission**	🇺🇸
April 1993	**Wide-Angle Michelson Doppler Imaging Interferometer** (WAMDII)	🇺🇸
June 1993	**Polar Mission**	🇺🇸
1993?	**Interball**	☭ esa
1994	**Radar Satellite** (RADARSAT)	🇺🇸🇨🇦
February 1995	**NASA Scatterometer Experiment** (NSCAT)	🇺🇸🇯🇵
December 1995	**Cluster Mission**	esa 🇺🇸
1996	**Earth Observing System** (EOS-1)	🇺🇸 esa
1996	**Regatta**	☭

Description
Since 1973, NASA and the National Oceanic and Atmospheric Administration have launched satellites to monitor cloud and storm patterns on Earth. *GOES* satellites will continue to be launched well into the 1990s.
Atlas 1 is a shuttle-launched mission that will last slightly longer than a week. Among the mission's goals are measuring the global distribution of various molecules in Earth's atmosphere.
NASA's *Upper Atmosphere Research Satellite* program will conduct the first global measurements of the chemistry, dynamics, and energetics of Earth's stratosphere, mesosphere, and lower thermosphere.
TOPEX will be launched using an Ariane-4 rocket in June 1992. The satellite will spend the next three years analyzing circulation patterns in Earth's oceans, relating its data to climate changes that occur on Earth's surface. The craft will also study heat and momentum exchange between the oceans and layers of Earth's atmosphere.
Launched using the space shuttle, the *Space Radar Laboratory* will orbit some 400 miles above Earth and create radar images of Earth's changing agronomy, botany, geology, geography, hydrology, and oceanography.
Using a spacecraft built by the Japanese Space Agency, *Geotail* is designed to study the energy stored in Earth's geotail and mid-magnetosphere. The spacecraft will conduct experiments for three years.
NASA's *Wind Mission* is a spin-stabilized spacecraft that will operate for three years. The craft will study the solar wind, using multiple instruments to sample plasma waves, energetic particles, and electric and magnetic fields.
The shuttle-launched *Wide-Angle Michelson Doppler Imaging Interferometer* will observe Earth's airglow and map atmospheric winds and temperatures as a function of altitude.
The spin-stabilized *Polar Mission* satellite will be used to study plasma, particles, and fields relative to Earth's polar regions. The mission will also image aurorae over a wide part of the spectrum to determine how energy transfer occurs between the solar wind and the Earth's magnetosphere.
Interball is a spacecraft venture involving fourteen nations that will study physical mechanisms of the solar wind and Earth's magnetosphere.
Radar Satellite will provide detailed radar observations of the changing patterns of sea ice, terrestrial ice, agricultural changes, global forestry trends, and other large-scale Earth phenomena visible from space.
Using the *NASA Scatterometer* to record changes in ocean wind speeds and directions, scientists at NASA and the Japanese Space Agency hope to understand the interaction of Earth's atmosphere with the oceans.
Cluster is a highly specialized project designed to perform three-dimensional studies of microphysical properties of different plasma states in Earth's magnetosphere.
A joint project of NASA, ESA, and the Japanese Space Agency, the *Earth Observing System* consists of four platforms containing a variety of instruments for geophysics research.
The Soviets plan to launch a system of satellites equipped with solar sails to study Earth's interaction with the solar wind.


Interaction of the solar wind and Earth's magnetosphere will be studied by several satellites


The U.S. *Geostationary Operational Environmental Satellite* program will provide high-quality weather data


The *Ocean Topography Experiment* will analyze circulation patterns in Earth's oceans

SPACE ASTRONOMY IN THE 1990s

SEEING THE UNSEEN SUN

A unique mission to explore the Sun's poles promises to give us the first three-dimensional view of our star.

by Richard Talcott

The Sun is a seething cauldron of hot gases. Vast amounts of radiation and large numbers of particles spew into space from the Sun's boiling surface. Unfortunately, from Earth we can sample only a very thin slice of the Sun; furthermore, this slice appears to be unrepresentative of the Sun as a whole.

Both ground-based astronomers and Earth-orbiting spacecraft are tied to a planet that orbits the Sun in a plane tilted only seven degrees to the Sun's equator. In the course of a year, therefore, Earth never manages to get more than seven degrees of solar latitude above or below the Sun's equator. Although astronomers can see sunspots, solar flares, and other features of the Sun's surface at many solar latitudes, they can directly sample only those parts of the Sun's disk that lie in the ecliptic plane.

Most visible solar features occur relatively low in the Sun's atmosphere or in the lower corona, where the density of the gas is quite high. Astronomers can identify atoms and measure magnetic-field strengths in these regions by taking the light produced and separating it into its constituent wavelengths. A bit farther from the Sun, however, the corona becomes very tenuous and there is no longer enough energy to generate the light that carries information to us.

To learn about the solar environment above the Sun's poles, we have to get above those regions and make direct measurements.

Although certain remote-sensing techniques give us a hint about the character of the corona and the solar atmosphere at high solar latitudes, these frequently produce ambiguous results. Consequently, to learn about the high-latitude regions of the solar environment, we have to get above those regions and make direct measurements.

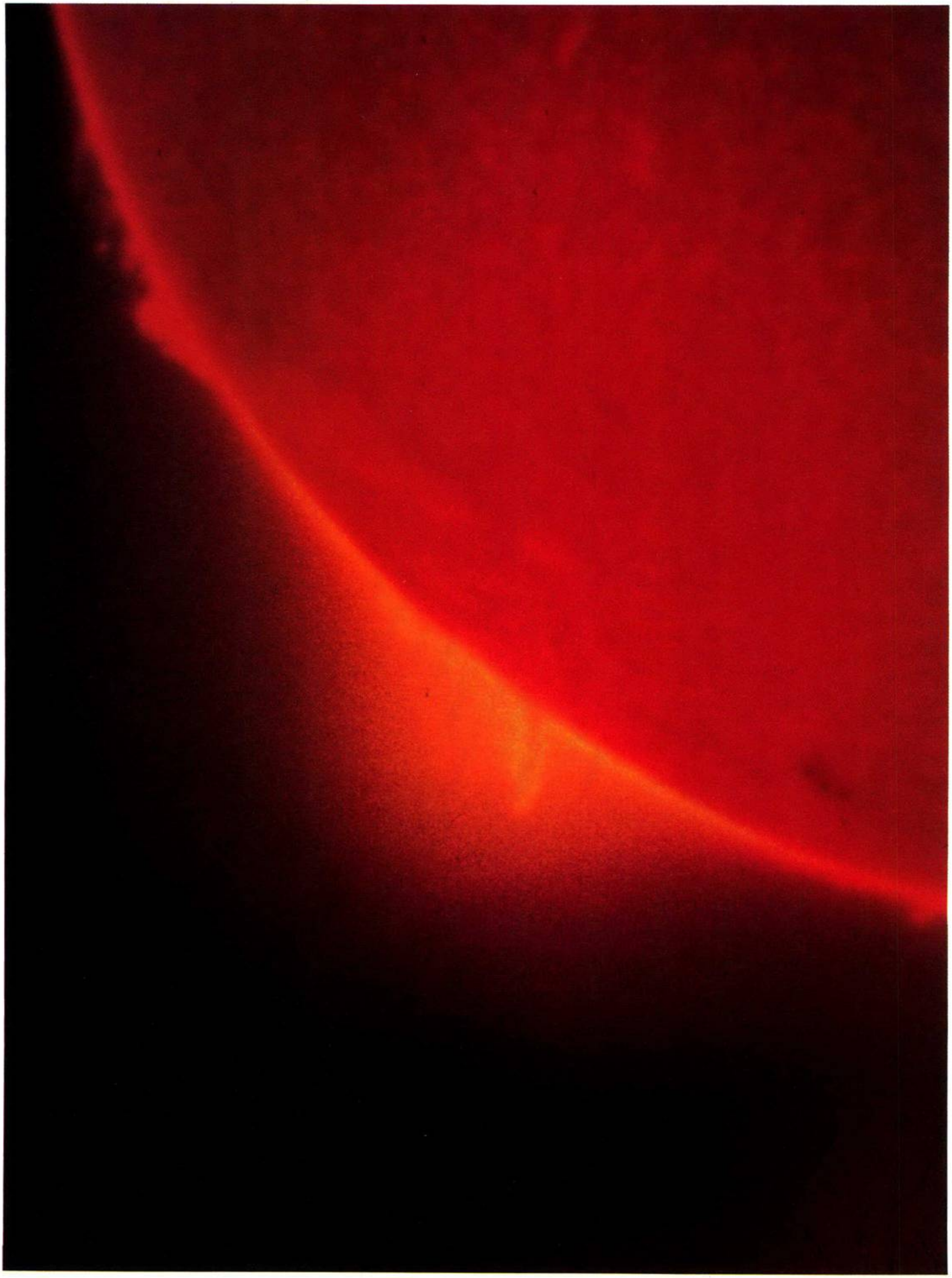
That is the goal of the *Ulysses* mission. *Ulysses,* a joint mission of NASA and the European Space Agency (ESA), is designed to fly out of the plane of Earth's orbit — the ecliptic — for the first time and sample the entire three-dimensional realm of the Sun. Scheduled for launch in October 1990, *Ulysses* will fly first to Jupiter, where the giant planet will sling the spacecraft out of the ecliptic. Some two-and-a-half years later, *Ulysses* will fly over the south pole of the Sun; nine months later it will fly over the Sun's north pole.

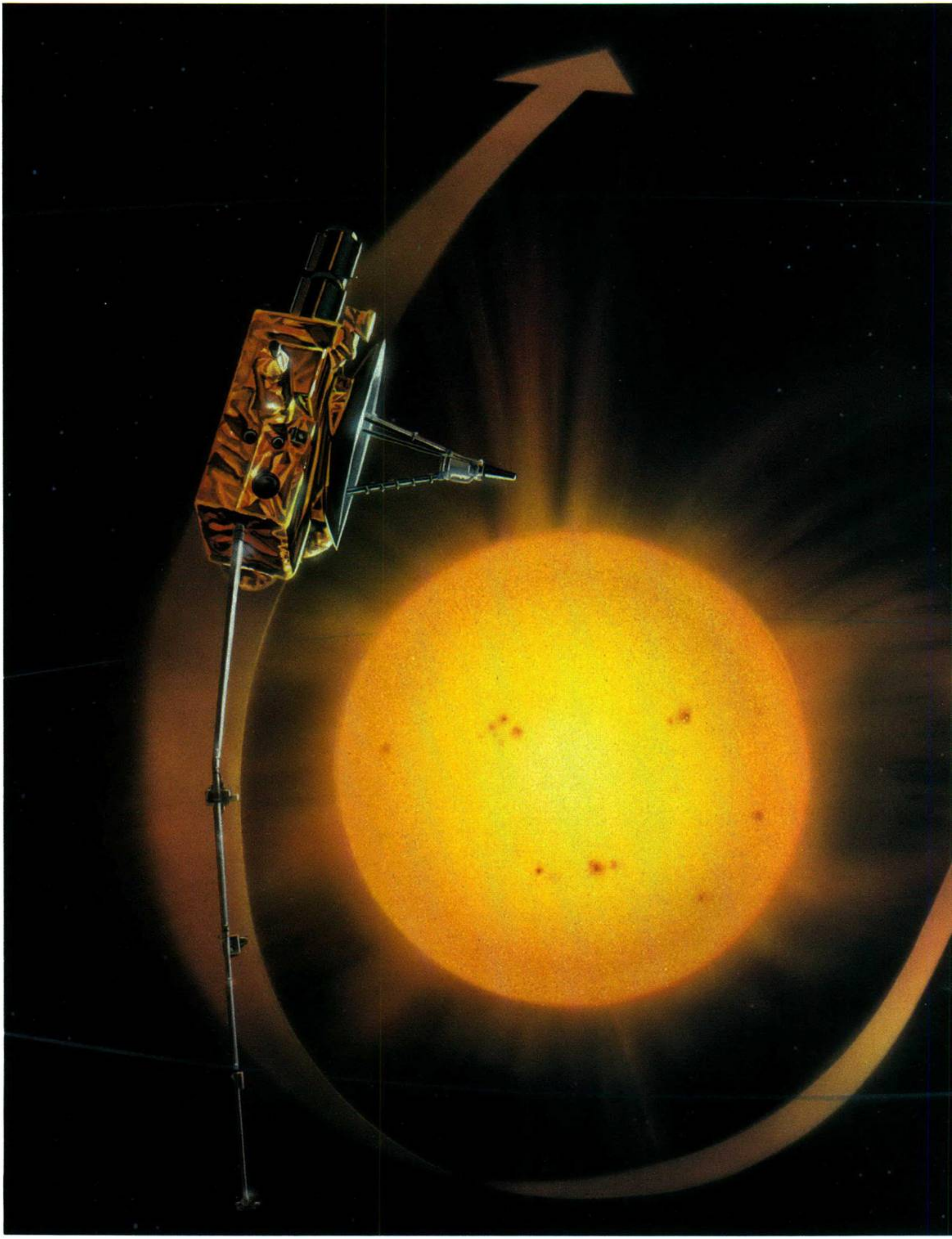
The solar atmosphere appears to flow more or less radially from the Sun, in a stream called the solar wind. In early March when Earth lies 7° south of the Sun's equator, the magnetic fields in interplanetary space near Earth are similar to those seen at the same time on the surface of the Sun's southern hemisphere. Likewise, in early September when Earth lies 7° north of the Sun's equator, the interplanetary magnetic fields near Earth are similar to those on the solar surface in the Sun's northern hemisphere. Disturbances in Earth's geomagnetic field occur not when a solar flare appears on the limb of the Sun, but only when solar rotation brings a flare on to the Sun-Earth line. These observations imply that the Sun's atmosphere expands nearly radially and that magnetic fields and other patterns near the Sun are transported unchanged great distances.

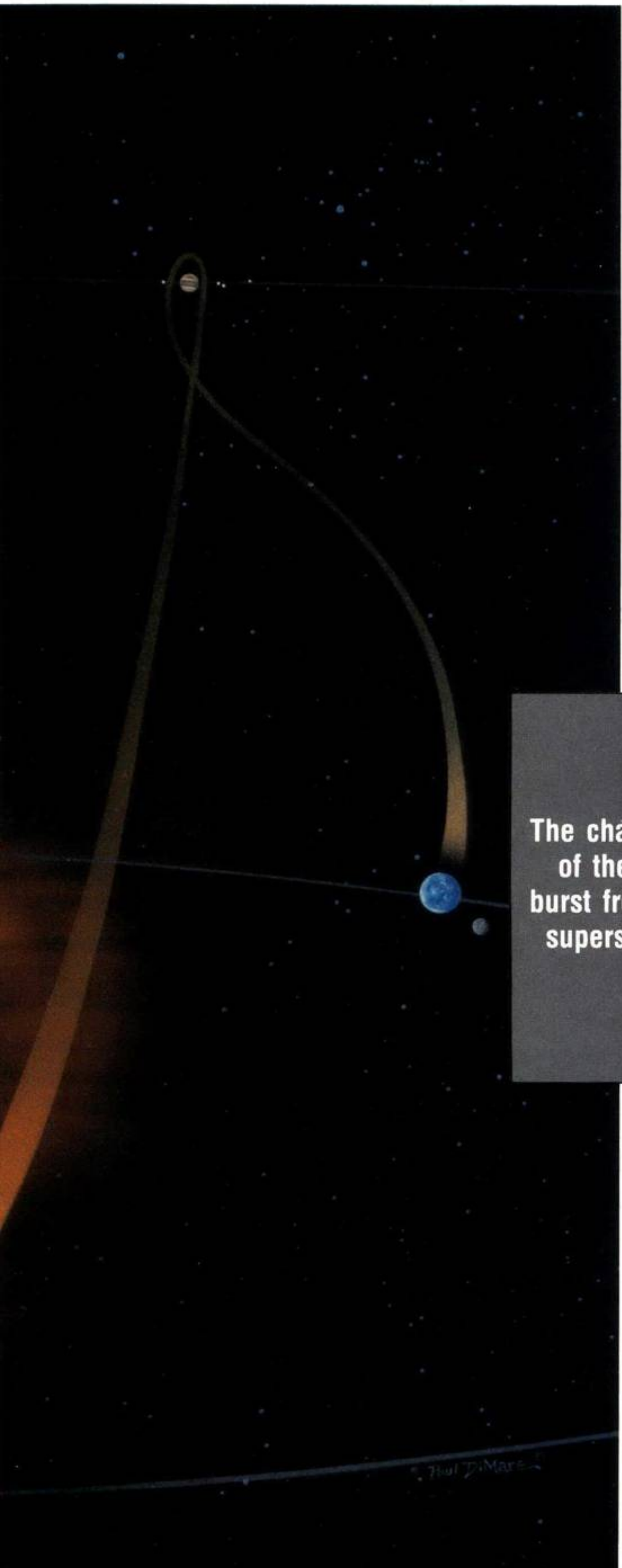
The first evidence that the Sun isn't the same at all latitudes came from the most prominent form of solar activity: sunspots. As the number of sunspots increases during the eleven-year cycle of solar activity, the average location of the sunspots migrates from about 30° solar latitude down to about 5° solar latitude in both the northern and southern hemispheres. Thus most of the time, particularly early in each sunspot cycle, scientists cannot directly sample the latitudes where most solar activity occurs.

The solar wind leaving these active areas is very significant on Earth. Scientists suspected more than one hundred years ago that the eleven-year solar cycle gives rise to an eleven-year cycle in disturbances in Earth's magnetic surroundings. We now know that such disturbances create beautiful aurorae, but they can also disrupt radio communications on Earth and interfere with electrical power grids. For a long time scientists were reluctant to acknowledge a relationship between solar activity and geomagnetic disturbances because they could not identify the mechanism responsible for the

HOT GASES ERUPT MAJESTICALLY into the Sun's corona. Astronomers' view of such activity is limited when it occurs at high solar latitudes. Photo by John Hicks.







AFTER ESCAPING THE ECLIPTIC PLANE with an assist from Jupiter, the *Ulysses* space probe explores the three-dimensional Sun for the first time.

link. But spaceflights have confirmed that electrically charged particles flow approximately radially from the Sun and their interaction with Earth's magnetic field can explain the link.

These electrically charged particles — the solar wind — originate in the Sun's corona. The corona is very hot, with a temperature over 1 million kelvins, and astronomers don't fully understand why. Ions and electrons are normally bound to the Sun by gravity, but at the high temperatures of the corona they overcome this gravitational attraction and burst away at supersonic speeds. The charged particles flow at an average speed of 450 kilometers per second, but they move much faster when activity increases on the Sun's surface. The supersonic flow engulfs Earth and stimulates activity in the geomagnetic field. From above the Sun's poles, *Ulysses* will be able to observe the solar wind in its most pristine form, which should aid astronomers' attempts to understand both the wind and the heat of the corona.

Looking at the Big Picture

We now know that our Sun is not the only star with a high-speed wind of charged particles. Spectroscopic studies of distant stars reveal that winds of charged particles are quite common. As a star rotates, each escaping particle carries away a tiny part of the star's angular momentum. The combined action of all the particles in the stellar wind slows down the star's spin. The exact effect of the wind on a star's rotation depends on which regions of the star give birth to the wind. Our proximity to the Sun puts us in a privileged position to study the solar wind, and these studies in turn can help us understand what goes on in stars hundreds of light-years away.

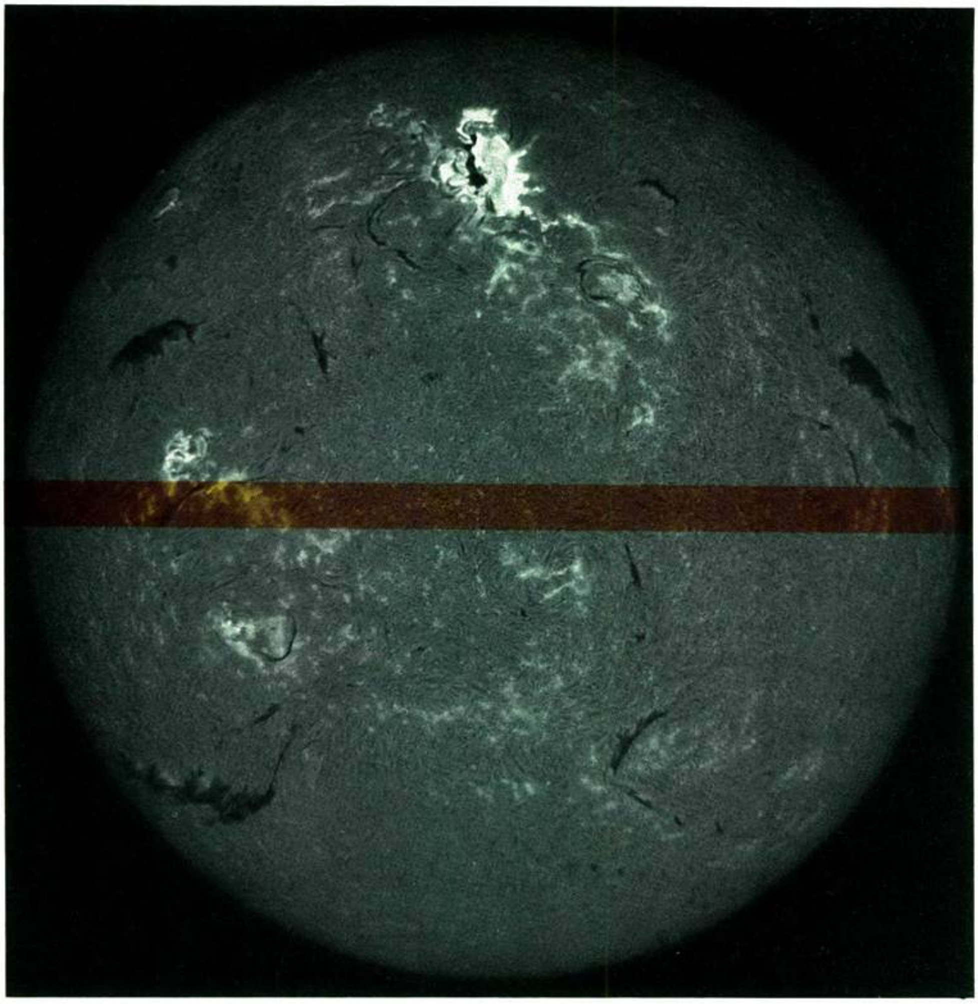
The charged particles of the solar wind burst from the Sun at supersonic speeds.

Although the solar wind blows continuously, its density and velocity are always changing. Much of this variation seems to be associated with coronal holes — regions where few x-rays are emitted. These regions appear as dark "holes" in x-ray photos of the Sun. Astronomers now suspect that energetic gusts of the solar wind, with velocities up to about 1,000 kilometers per second, originate in coronal holes. During the quiet part of the solar cycle, these coronal holes occupy large regions and are centered on the Sun's poles. At more active times the polar coronal holes tend to shrink and "miniature" holes may appear for short periods at other solar latitudes.

Because the solar wind flows radially from coronal holes, we won't really see what's going on in the solar wind until we get measuring instruments above the coronal holes. The desire to know the distribution of the solar wind is just one of many reasons to send *Ulysses* to explore the uncharted solar latitudes.

Blowing in the Solar Wind

The solar wind also carries magnetic field patterns at the surface of the Sun out to great distances. From measurements made by the *Voyager* and *Pioneer* spacecraft, we know this distance is at least 50 astronomical units (AU) (fifty times the average distance between the Sun and Earth, or approximately 7.5 billion kilometers). This volume of space in which the expanding solar wind and its magnetic field are in control of the situation is



***ULYSSES* WILL EXPLORE** the Sun from all solar latitudes, not just above the 14°-wide strip that astronomers can sample directly from Earth.

called the heliosphere, from the Greek word for Sun, *helios*.

As the solar wind carries magnetic fields from the Sun's equator into interplanetary space, solar rotation winds them into spiral patterns. At the Sun's poles, where there is no rotation effect, the magnetic fields are probably radial. If they are radial, they would not be twisted into the complex shapes found in the ecliptic plane and should be easier to comprehend. The magnetic field pattern found in a volume of interplanetary space is determined by two factors: the patterns originally present at the Sun (which depend strongly on solar latitude) and the way these patterns are carried by the solar wind.

The background solar magnetic field is dipolar, like the north/south magnetic field surrounding an ordinary bar magnet. The solar wind stretches this dipolar field so that at large distances from the Sun, magnetic field lines going outward from the Sun's northern hemisphere are separated from those returning to the Sun in the southern hemisphere by a neutral current sheet. The current sheet lies approximately at the latitude of the Sun's equator. The sheet is not flat, but warped, much like a phonograph record left outside on a hot, sunny day. As the Sun rotates — once every twenty-seven days as seen from Earth — the northern heliosphere, characterized by magnetic fields of one polarity, sweeps over Earth; about two weeks later the beam from south of the current sheet, which carries the opposite magnetic polarity, passes Earth. There tends to be little warping of the current sheet near sunspot minimum, but during periods of high solar activity it appears that the sheet can be severely warped, perhaps reaching solar latitudes of 60° at some longitudes. Every eleven years, following solar maximum, the polarity of the solar dipole magnetic field reverses.

Astronomers have extrapolated "knowledge" of these three-dimensional phenomena from direct measurements made in the ecliptic plane and observations of the solar surface made from Earth. In order to ensure that these ideas make sense, we need to travel out of the ecliptic plane and into the third dimension of the heliosphere to make direct measurements. This is what *Ulysses* is designed to do.

Ulysses will measure magnetic fields using two different types of magnetometers. Both sensors are mounted at the end of a long boom to separate them from the magnetic "noise" of the spacecraft subsystems. The two magnetometers will also be able to discriminate between spacecraft-generated fields, which fall off rapidly with distance and thus give rise to fields of different magnitudes at the two sensors, and solar magnetic fields, which are constant over the dimensions of the spacecraft and boom.

Radiation from beyond the Solar System

Not only will *Ulysses* study the Sun in three dimensions, but its unique trajectory will enable it to study some aspects of the universe that are difficult to study from the ecliptic plane. One key area of study will be cosmic-ray physics. Cosmic rays are highly energetic charged particles that move through space at nearly the speed of light. Some similar, high-energy nuclear particles come from intense disturbances on the Sun; astronomers think that cosmic rays similarly originate at times of outburst or explosion on distant suns.

Astronomers' understanding of the nature of cosmic rays is limited because the "virgin" flux of particles originating in the Galaxy or beyond is severely modified as the cosmic rays pass through the heliosphere. The eleven-year sunspot cycle clearly influences the number of cosmic rays detected on Earth; so when solar activity is at a maximum, the amount of cosmic radiation is at a minimum. Although we don't know what causes this variation, one hypothesis is that the heliosphere gets bigger when the Sun is more active and thus provides a larger obstruction to the arriving radiation. Some recent observations even suggest that the warp of the current sheet affects the ability of cosmic radiation to penetrate the heliosphere. With the data *Ulysses* returns from the high solar latitudes beyond the current sheet, we hope to learn how the magnetic fields modulate the arriving cosmic rays.

Ulysses may even be able to go one step further and observe unadulterated cosmic radiation. As the spacecraft flies over the solar poles, we could see cosmic rays that have entered the heliosphere unopposed along the Sun's magnetic field lines. This would give us the first direct measurement of the distribution of high-energy nuclear particles born of catastrophes in distant stars.

To record and identify high-energy cosmic rays, *Ulysses* uses what is often called a charged-particle telescope. The basic charged-particle telescope consists of two elements that register the passage of a charged particle. In many cases the front element is a thin piece of silicon, typically 50 microns thick (1 micron is one-millionth of a meter), and the second element is another piece of silicon several millimeters thick. A charged particle entering the telescope generates a small electrical signal in each element. This signal is proportional to the amount of energy deposited there. The pair of signals generated by the two telescope elements allows astronomers to identify the cosmic-ray particle that passed through the telescope and determine the total energy of the charged particle. The telescope also determines the arrival direction of the cosmic ray by recording only those particles that pass through both elements. For each cosmic ray recorded, astronomers will know the identity of the particle, its energy, and its arrival direction.

Ulysses will carry a sophisticated set of multi-element detectors of various thicknesses and materials; thus the nature of the cosmic radiation and its direction can be recorded over a very large energy range. Indeed, some of the detectors are so sensitive that astronomers will be able to identify which isotope of a particular species has been found. This information provides clues about where the cosmic ray was generated and the path it traveled to reach the solar system.

Ulysses may give astronomers their first direct look at the high-energy cosmic rays born of catastrophes in distant stars.

Checking on Einstein

The most exotic goal of the *Ulysses* mission may well be the search for gravitational waves. Einstein's general theory of relativity predicts that gravitational waves — ripples in the curvature of space-time that propagate through space at the speed of light — should be created in catastrophic events such as a supernova explosion or the collapse of a galactic nucleus into a supermassive black hole.

To date, no gravitational waves have ever been detected directly. However, the *Ulysses* spacecraft may be able to do so. A passing gravitational wave would cause a barely detectable change in the spacecraft's orbit. The position of *Ulysses* will be tracked very accurately using information from the radio signals traveling to and from the spacecraft. If a gravitational wave passes the spacecraft during its flight and if the required accuracy is achieved, *Ulysses* will be able to detect it. The discovery of a gravitational wave would be a big step forward in checking the validity of general relativity.

Getting There

The reasons for sending a spacecraft out of the ecliptic have long been clear. The earliest proposal for an out-of-ecliptic mission came in 1959, at the dawn of the Space Age. At first there were no launch vehicles with enough thrust to get a spacecraft out of the ecliptic plane. Although space agencies had committees to select missions to study the Sun, Earth, and the other planets, there was no special committee to study the heliosphere.

In the early 1970s the European Space Agency performed a Mission Definition Study for an out-of-ecliptic mission and proposed cooperation with NASA. In 1977 the two agencies approved the *International Solar Polar Mission,* an ambitious project that would send two spacecraft, one each built by ESA and NASA, to the Sun. Two spacecraft would provide researchers with a stereoscopic view — one spacecraft would sample the heliosphere from above the ecliptic plane while the second would sample below it. In 1981, however, NASA faced a severe budget cutback and canceled its spacecraft. This delayed the launch of the ESA craft by three years, to 1986. The *Challenger* accident in January 1986, however, delayed the launch an additional four years.

After long years of frustrating delays, *Ulysses* now appears on target for an October 1990 launch. NASA will provide the Shuttle launcher, the spacecraft's power supply, tracking, and the recovery of data. ESA will provide the spacecraft, the integration of the science instruments, and a spacecraft operations team. The scientific instruments come more or less equally from European and American scientists; over 120 scientists at 47 institutions are currently involved.

Getting The Right Trajectory

If all goes according to schedule, next October the space shuttle *Atlantis* will carry its payload into an orbit about 200 kilometers above Earth. Part of the payload will be the *Ulysses* spacecraft, mounted on a Payload Assist Module version S (PAM-S) motor that in turn is mounted on an Inertial Upper Stage (IUS) solid-fuel rocket. When *Atlantis* is established in orbit, it will act as a launch pad from which the IUS and PAM-S rockets will be fired to send *Ulysses* on its way toward Jupiter.

Jupiter is *Ulysses'* first stop because there are currently no launch vehicles capable of generating the thrust necessary to get a spacecraft out of the ecliptic plane. *Ulysses* will get part of the enormous thrust it needs to get into a solar polar orbit from the launch vehicle and the rest from the gravitational pull of the giant planet Jupiter. Launch vehicles generally travel in the same direction as Earth's spin (west to east) and in the plane of Earth's orbit, both of which provide the craft with a boost. Without this natural send-off boost, a spacecraft requires enormous amounts of vehicle thrust. Unfortunately, a spacecraft trying to get into a plane perpendicular to the ecliptic can't use any of this natural boost.

An object orbiting the Sun at a distance of 1 AU must move at a speed of 30 kilometers per second. In the case of Earth, this velocity is entirely in the ecliptic plane. For a spacecraft to get into a polar orbit, the velocity has to be perpendicular to the ecliptic plane. To launch an out-of-ecliptic mission directly from Earth, the existing in-plane component must be countered by an equal and opposite velocity, and a perpendicular velocity component must be supplied. This means the craft would need to be accelerated to a speed of 42 kilometers per second to reach a polar orbit at the distance of Earth.

Sending the spacecraft to Jupiter first solves several problems. The velocity of Jupiter in its orbit around the Sun (14 kilometers per second) can be used to cancel an equal and opposite component of the spacecraft's in-plane velocity. Furthermore, the required velocity perpendicular to the ecliptic needed at Jupiter's distance from the Sun is only about 16 kilometers per second. Thus, the required launch vehicle capability is much smaller, by a factor of 2.5, compared with the Earth-launch scenario.

Jupiter's role is similar to that of a stair banister used to descend a flight of stairs quickly. Imagine that you're running along a corridor and are in a hurry to descend a flight of stairs at right angles to the corridor. You would grab hold of the banister to swing yourself into position. The force applied by the grabbing hand and arm causes an abrupt change in your direction; Jupiter's gravity does the same job for *Ulysses*. To make the analogy even better, visualize replacing the banister with a human hand able to pull on the grabbing hand of the passing traveler. Of course, the angle of approach must be correct, the approach speed must be high but not too high, and the hand must hold on long enough but not too long, or a disaster would occur. *Ulysses'* approach to Jupiter must be planned with similar precision.

The spacecraft will use the gravitational pull of Jupiter to escape the confines of the ecliptic plane.

Jets on the spacecraft will steer *Ulysses* so that it approaches Jupiter from the north. When it arrives in December 1991, Jupiter's gravity will pull the spacecraft with a force (always directed toward the center of Jupiter) that will cause it to swing south and out of the ecliptic plane. From this point on, *Ulysses* will come under the control of the Sun's gravity and orbit like a planet moving in a plane perpendicular to the ecliptic. In April 1994 *Ulysses* will fly about 2 AU above the Sun's south pole and nine months later fly the same distance above the Sun's north pole.

The Spacecraft

Ulysses weighs 370 kilograms and measures about 3.3 meters wide by just over 2 meters high with its booms stowed. It carries several booms that serve as antennas or mounts for the scientific instruments, which need to be some distance from the spacecraft body. The two longest booms act as dipole antennas and measure 72.5 meters from tip to tip.

Of the 370-kilogram total weight of *Ulysses*, some 55 kilograms are devoted to nine scientific instrument packages. In addition to the pair of magnetometers and the collection of charged-particle telescopes mentioned earlier, *Ulysses* will carry two experiments to study the solar wind, a plasma experiment, and an ion composition experiment. Its payload also includes the HI-SCALE experiment to study low-energy ions and electrons in the heliosphere; an energetic ion composition experiment to measure the energies, masses, intensities, and spatial variation of particles in the solar wind as well as the amount and direction of arrival of interstellar neutral helium; an experiment to observe radio waves emitted by the Sun and plasma waves in the solar wind; the solar x-rays and cosmic gamma-ray bursts experiment; and an experiment to study dust in the solar system.

The solar cells typically used on near-Earth spacecraft can't provide enough power to *Ulysses* when it is out near Jupiter, where sunlight is only 4 percent as strong as on Earth. Thus the spacecraft derives its power from a Radioisotope Thermoelectric Generator (RTG). The RTG is not a nuclear reactor, but simply a box of radioactive material that decays over a period of time. The radioactive decay gives off heat, which in turn is converted to electricity by thermocouples. The RTG delivers about 290 watts of power in this way. Similar power supplies have been used successfully on the various *Pioneer* deep-space probes, both *Voyager* spacecraft, and the *Galileo* mission to Jupiter.

The parabolic antenna on *Ulysses* will beam back data at a rate of 1,024 bits per second. The NASA Deep Space Network and the Mission Operations Manager and his team from ESA — all working out of the Jet Propulsion Laboratory in Pasadena — will "listen" to the spacecraft eight hours each day. There will be no break in the continuity of the science data during the other sixteen hours because all the data will be stored in onboard tape recorders. The stored data will be relayed back to Earth during the next eight-hour listening period.

Ulysses will allow man to escape the confines of the two-dimensional ecliptic plane for the first time and from there to investigate the mysteries of the high-latitude regions over the Sun's poles. Not only do astronomers expect to learn a great deal about the solar atmosphere and its continual battle with arriving cosmic radiation, but this first three-dimensional study of a star and its environs could provide valuable clues for our understanding of the behavior of distant stars and of astronomy on a cosmic scale.

This long-awaited, path-breaking mission began with the name Out-of-Ecliptic, and for a time it became the *International Solar Polar Mission*. The name was changed to *Ulysses* in 1984 at the suggestion of one of the scientists on the mission. A passage in Dante's *Inferno* tells us that Ulysses, after returning home to Ithaca, soon became restless and set off on a new journey to explore the then unknown world beyond Gibraltar. He exhorted his companions "To venture the uncharted distances . . . of the uninhabited world beyond the Sun . . . to follow after knowledge and excellence." These lines seemed to capture the spirit of the first space mission over the solar poles. And who can guess what really lies beyond "Gibraltar?" □

The author wishes to thank Dr. D. Edgar Page, the European Space Agency Ulysses *mission science coordinator at the Jet Propulsion Laboratory in Pasadena, California, and Dr. Edward J. Smith, the NASA project scientist for* Ulysses, *for supplying the information on which this article was based.*

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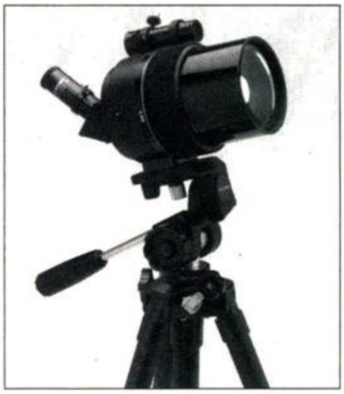

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SPACE ASTRONOMY IN THE 1990s

THE PROMISE OF THE SPACE TELESCOPE

From the solar system to the edge of the universe, no region of the cosmos will escape the *Hubble Space Telescope*'s penetrating eye.

by Stephen P. Maran

The launch of the *Hubble Space Telescope* is imminent. After more than a decade of planning and preparation, the focus of activity is now shifting to the objects *HST* will observe: the celestial targets selected by the hundreds of astronomers who will conduct initial studies with the 2.4-meter orbiting reflector.

One thing most of these astronomers agree on is that just about every observation planned for *HST*'s first years of operation represents a step into the unknown and as such has the potential of opening up a new avenue to understanding what makes the universe tick. If *HST* can accomplish this, the long wait will have been worth it.

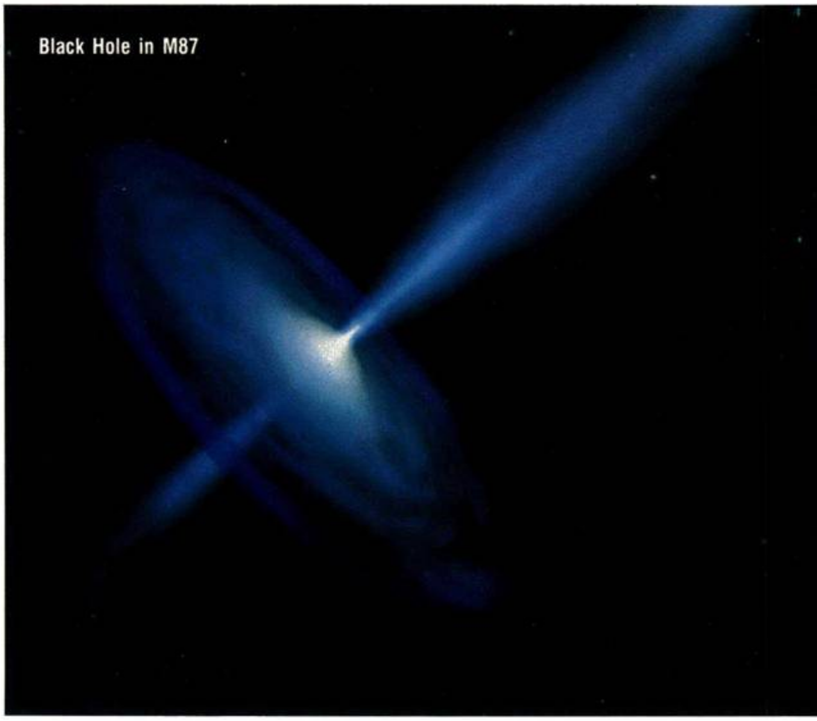
One of the biggest topics *HST* will address is the distance scale of the universe. How far away are the galaxies? How fast is the cosmos expanding? How large is the universe? The answers to these and many other fundamental questions depend crucially on getting accurate distances to a large number of objects in the universe. And *HST* is uniquely qualified to determine those distances.

Fittingly, the great American astronomer for whom the *Space Telescope* is named, Edwin P. Hubble, played a key role in early attempts to learn the scale of the universe. Hubble discovered that the universe was expanding, and he was the first to measure the present rate of expansion. However, current estimates of the expansion rate, known as the Hubble constant, range from 50 to 100 kilometers/second/megaparsec. In other words, this vital number is uncertain by a factor of two.

In practice, distances to most extragalactic objects are determined by their redshifts. The redshift tells how far toward the red end of the spectrum the object's spectral lines have been shifted, and that in turn is a direct measure of the object's recessional velocity. To find the distance to an object in megaparsecs, astronomers divide recessional velocity, expressed in kilometers per second, by the Hubble constant.

For example, if a galaxy recedes from Earth at 10,000 kilometers per second, its distance is just 10,000 divided by the Hubble constant. Using a Hubble constant value of 100 yields a distance of 100 megaparsecs; using a value of 50 yields a distance of 200 megaparsecs. Just as the Hubble constant is uncertain by a factor of two, any distance derived from it is uncertain by a factor of two. Every time you read that some distant quasar is "12 billion light-years from Earth," remember that this is a very rough number and does not mean astronomers have established the distance accurately. That should change with *HST*, however. Astronomers plan to use *HST* to determine the Hubble constant by several independent techniques, so that we can at last get accurate ranges to distant objects.

One of the techniques involves observing Cepheid variable stars in other galaxies. Henrietta Leavitt, the early 20th-century Harvard Observatory astronomer, discovered the period-luminosity relation for Cepheid variable stars. According to the period-luminosity relation, the longer it takes a Cepheid to fade from maximum to minimum brightness and then to return to maximum brightness again, the brighter the absolute magnitude of the Cepheid. By observing the light curves of Cepheid



Black Hole in M87

variables in nearby galaxies, astronomers can determine the variable's absolute brightness. Comparing this value with the star's apparent brightness then gives a good estimate of the galaxy's distance. *HST* promises to extend this technique much farther into the universe.

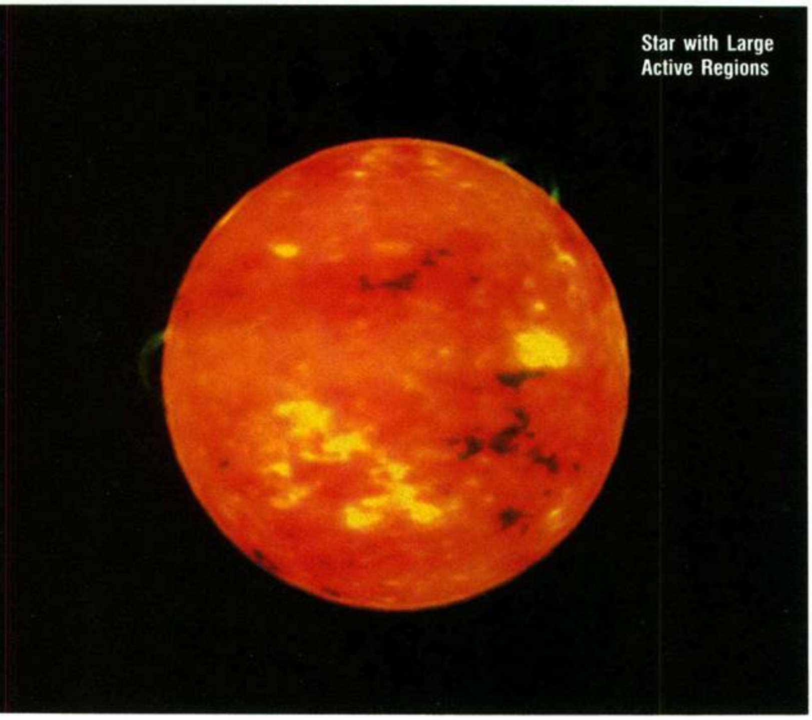
James Westphal of the California Institute of Technology, who leads the *Space Telescope*'s Wide Field and Planetary Camera (WF/PC) science team, will use the high resolution and superb sensitivity of the WF/PC to discover and monitor Cepheids in the Virgo Cluster of galaxies (and elsewhere), tens of millions of light-years from Earth. Once this has been done, we'll know exactly how many tens of millions of light-years away these galaxies are. And because the redshifts of the galaxies in this cluster are well known, we'll get a much more precise estimate for the Hubble constant.

In each galaxy observed, two fields will be photographed with *HST* at regular intervals. The problem is that the WF/PC team not only has to discover the Cepheids and sample the light curves often enough to establish accurate periods, they must do so while using as little telescope time as possible. And of course, they want to see the light curve repeat to make sure they've measured it right. Westphal says that their observing strategy "has been crafted to maximize the sampling of any one Cepheid, getting enough to define its cycle. We take an exposure, then another one two days later, then another after 4.3 days from the start, then 6.9 days, 10 days, 13.5 days, 22.4 days, 27.9 days, 34.2 days, 41.5 days, and finally at 50 days."

Many of the other attempts to measure the Hubble constant with *HST* use other objects as distance indicators. As long as the objects have well determined absolute magnitudes, they'll work. Jeremy Mould of Caltech will study nearby galaxies using Cepheids, supernovae, and the brightest resolved stars. And William E. Harris of McMaster University in Canada will try to determine the Hubble constant by observing globular clusters in giant elliptical galaxies in the distant Coma Cluster.

Deciphering the Stars

Many astronomers, myself among them, have their sights set closer to home: on individual stars in our galaxy. This may not sound as exciting as determining the distance scale of the universe, but there are many observations that must be made with *HST* if we are going to learn how stars and stellar evolution work. For example, Andrea Dupree of the Harvard-Smithsonian Center for Astrophysics and Erika Bohm-Vitense of the University of Washington will each be trying to find out where red giants shed their mass. The "where" they are seeking is not a place in the Milky Way but a region on the Hertzsprung-Russell diagram, the famous chart that plots stars according to their magnitudes and temperatures. According to present theory, when a red giant starts to burn helium in its core, it evolves from a cool red giant into a small, hot, and blue "horizontal-branch" star. The problem, says Bohm-Vitense, is that "the horizontal branch stars are less massive than the red giants," but there is no experimental measurement of the exten-



Star with Large Active Regions

sive mass loss that must occur for the giants to be transformed this way.

There is evidence, however, of some strange behavior among the red giants at this evolutionary stage. Heroic efforts with the *International Ultraviolet Explorer*'s 17-inch telescope, which involved taking exposures longer than sixteen hours to get one spectrum of one red giant in a globular cluster, show that as these stars age "their chromospheres get stronger, like a fine cognac," Dupree notes with a smile. But present theory predicts that a star's chromosphere — the relatively hot layer of a star's atmosphere that lies above its visible surface —should weaken as the star gets older and its atmosphere swells.

IUE is barely sensitive enough to reveal the chromospheric emission lines in globular cluster red giants; to investigate further astronomers need much better spectra that show the shapes of the spectral lines. Bohm-Vitense explains that *HST*'s Goddard High Resolution Spectrograph (GHRS) can obtain "high-resolution spectra that should show blue-shifted absorptions" in the profiles of the chromospheric emission lines of singly-ionized magnesium near a wavelength of 2800 angstroms. The strengths of the absorption lines will tell her how much mass flows from the red giants in her target globular cluster, NGC 6397, while the blue shift of the absorption lines will tell her how fast the material streams from the stars. Dupree will investigate mass loss in red giants in other globular clusters, including Alcaino 59 (named for astronomer Gonzalo Alcaino) and NGC 6752. She'll take exposures of 100 minutes or less with the GHRS, in contrast to the sixteen to seventeen hours required for observing two of the same stars at a lower spectral resolution with *IUE*.

My own studies with *HST* include three projects in collaboration with Bruce Woodgate of NASA's Goddard Space Flight Center and other colleagues to observe stellar coronas, the outermost part of a star's atmosphere. The sensitive x-ray detectors on the *Einstein* satellite (*HEAO-2*) showed that many stars have hot, dense coronas, but revealed little about the physical state of the coronal gas. Is the entire corona of a given star at a single temperature of a few million degrees or are there layers or localized regions at a few hundred thousand degrees, others at a million degrees, and still others at higher temperatures? Do these regions coexist and perhaps change with starspot activity and stellar flares?

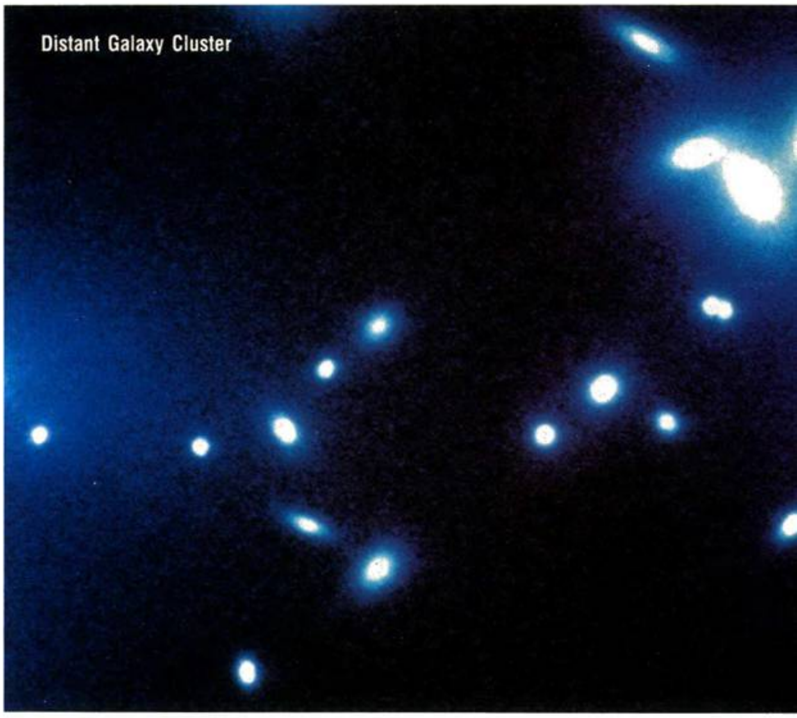
In one project with the GHRS, colleagues from several laboratories will join me in monitoring the southern star AU Microscopium for more than three hours with *HST*. AU Mic is a flare star, a small, intrinsically faint red star that is prone to sudden and intense outbursts of radiation. Although ground-based observers might see only minor flares in visible light during this time, I suspect that the ultraviolet lines arising in the corona of such a star will brighten dramatically. (These lines have been detected only in the Sun thus far, but they should be seen easily with *HST*'s GHRS.) This should hold true even when the visible light, which arises in the star's photosphere and chromosphere, changes by a tenth of a magnitude or less.

If all goes according to plan, University of Maryland radio astronomers Mukul Kundu and Stephen White will be monitoring AU Mic with the Very Large Array radio telescope at the same time *HST* is trained on the star. Concurrently, Goddard's Kenneth Carpenter and perhaps astronomers in Europe will be directing *IUE* observations of AU Mic. We hope that by watching AU Mic with *IUE* for several days before and after the *HST* observations, we will be able to determine the location and level of activity of any huge disturbed regions on the star during those precious three hours.

The Search for Extrasolar Planets

Most astronomers think that the planets in our solar system are just the tip of a giant iceberg, that countless other planets circle stars throughout our the universe. But proving that these planets exist is an enormous observational challenge. Any such planet would shine very faintly and appear so close to its much brighter star as to be lost in the overwhelming glare.

The *Space Telescope* could change all that. From its vantage point in space, *HST* will achieve a much higher resolution than ground-based telescopes can, and this will allow astronomers to search for planets deep into the regions surrounding stars. Although no one can be certain that any planets will be found, the search for them is one of the most active areas of research for the



Space Telescope.

Stephen E. Strom of the University of Massachusetts will lead a large effort to locate planets with *HST* by studying the circumstellar dust disks in which they are thought to form. Strom is targeting T Tauri stars, stars with a mass similar to the Sun's that have only recently formed out of the interstellar medium. He believes many of these young stars are surrounded by dust disks that might harbor planets. Strom hopes that high-resolution images taken with *HST*'s WF/PC will show the disks. (In the Planetary Camera mode the WF/PC can resolve features as small as 0.043 arcseconds across, which is about ten times better than possible from the ground.)

Images taken through various filters may also tell astronomers about the dust particles that make up the circumstellar disks. For example, by comparing the brightness of a disk photographed at a far red wavelength with the brightness of the same disk shot in ordinary visible light, astronomers can estimate the size of the dust particles. Strom states that the ratio of the brightnesses "will indicate whether the particles are much larger than ordinary interstellar particles." If they are much larger, it might indicate that the dust has begun to stick together, a process that could lead to planet formation.

On the other hand, a disk with oversized dust particles might be a planetary system in a later stage, where the dust particles observed come from larger bodies that have already formed (maybe planetesimals) and are now colliding together. "If I get a photo of one of these disks," Strom says, "it will be one of the most exciting moments of my life."

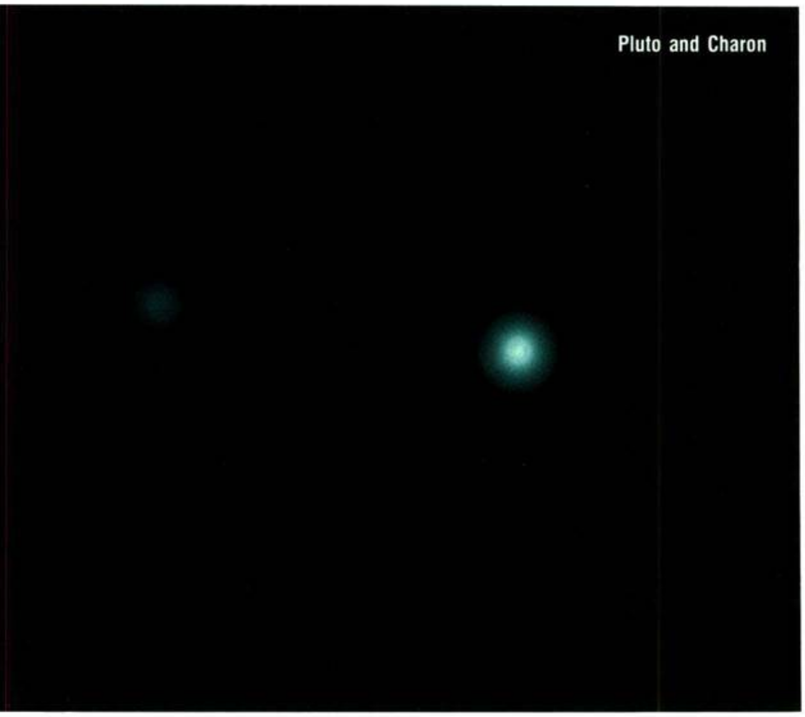
Of course, *HST* photographs might show that Strom's disk idea is offbase. They might reveal instead that the dust around T Tauri stars is strewn in a helter-skelter pattern of blobs, not in a neat disk. In that case the dust would more likely be the remains of the interstellar material from which the star condensed rather than a signature of planetary formation. But even that would be a fascinating discovery.

To find planets in the circumstellar disks, Strom will try to obtain images sharper than the 0.043-arcsecond camera pixels. To do this he'll take several exposures of the same star, each with the telescope pointing in a very slightly different direction. By moving *HST* between exposures, Strom causes the image of the star to move by an equivalent amount (a carefully chosen, non-integer multiple of 0.043 arcseconds). This trick should allow Strom to glean information that is ordinarily lost due to the finite size of the electronic camera pixels. It may also enable astronomers to achieve the full optical performance *HST*'s superb mirrors are capable of.

There's no guarantee that Strom's method will detect planets; the planets may be too faint or they may not be in the places where Strom looks. But even if his search for extrasolar planets fails, any one of several other searches may succeed. James Westphal plans to look for a telltale sign of planets — wobbling in the motions of their parent stars — by making use of the WF/PC's "Baum spot." This is a dark spot located on one of the otherwise well-aluminized optical flats inside the WF/PC. While the rest of the camera's field of view is very efficiently reflected to CCD detectors, the starlight that falls on the Baum spot is strongly suppressed. (The Baum spot is named for Lowell Observatory astronomer William Baum, who came up with the idea.) Thus, faint objects that would otherwise be lost in the star's glare can be detected.

Westphal explains his plan of attack: "We'll put a star on the Baum spot and take a deep exposure and repeat this four times a year for as long as we can get away with it." For each target star, they will search the images for distant background objects and make astrometric measurements of the target with respect to these reference points with what Westphal calls "milliarcsecond precision." If the observations reveal a tiny, systematic wobbling in the target star, the Westphal team will know that the star may have a very low-mass companion, perhaps a planet.

Westphal credits another planet hunter, William Fastie of The Johns Hopkins University, with one of the cleverest plans for finding planets with *HST*. Fastie's method derives from a few simple laws of optics. In the absence of atmospheric turbulence, precision optics like *HST*'s form an image of a bright star that consists of a bright spot surrounded by a series of bright and dark concentric circles called diffraction rings. The diameters



of the rings depend on the wavelength of light being observed. Clearly, the best place to look for a dim planet near a bright star is in the dark rings, because there's less interfering starglow. Fastie plans to photograph each of his target stars through filters that isolate light of different wavelengths. In effect, he will scan a dark ring over a range of distances from the star. This assures that no planet is overlooked simply because it falls on a bright diffraction ring in a single photograph.

Closer to Home

The still undiscovered planets of other stars are not the only planets on *HST*'s agenda. Alan Stern, an expert on the outer solar system from the University of Colorado, says that observers will devote about 130 hours to observing planets in the solar system during the first round of *HST* observations. And of those hours, 43 will be devoted to cold, distant Pluto. Why spend so much time on one small planet? Stern maintains that Pluto "is an object where *HST* can make tremendous strides, because it's the only planet that has not been visited by a spacecraft."

Stern leads a science team that will map the surface of Pluto with both the WF/PC and the Faint Object Camera. There's growing evidence that Pluto's surface has both bright and dark areas, but that's about all we know. Different experts have drawn different conclusions as to where the contrasting areas are located and how large they are. Stern wants to settle the matter by pinpointing the sizes and locations of these areas with his *HST* observations.

Stern also wants to investigate whether there are seasonal deposits of methane ice on Pluto, like the seasonal deposits of snow in temperate latitudes on Earth. If, as he suspects, the bright spots on Pluto are methane ice, then they must be seasonal, forming when Pluto is relatively far from the Sun and atmospheric methane condenses on the surface. These deposits disappear when Pluto is closer to the Sun and the frozen methane evaporates. There may be transport processes, bringing gaseous methane from warm areas to cold areas where it freezes out. If methane frosts on Pluto were not seasonal, but permanent, then solar ultraviolet light and cosmic rays would turn them black in just a few centuries as the constant irradiation induced methane molecules to join hydrocarbon chains.

How to resolve this problem? Unfiltered photos of the distant planet by *HST* will reveal where bright and dark spots are, providing maps of Pluto that will "look a little less detailed than a naked-eye view of the Moon," Stern says. Photos taken with filters that isolate wavelengths where methane molecules absorb light will reveal whether it is the bright areas or the dark spots of Pluto that harbor methane frost. If the bright areas are methane ice, Stern's ideas will be confirmed, but if the dark areas (or both bright and dark areas) are methane, someone will have to come up with a new theory.

Besides looking for new planets, *HST* will study new comets, or at least some astronomers hope so. John C. Brandt, comet specialist at the University of Colorado who leads the science team for *HST*'s Goddard High Resolution Spectrograph, has as his prime project the study of a bright new comet with the GHRS. "The trouble is, we missed Halley and we have no idea when the first suitable bright comet will come after the telescope finally is launched," Brandt says wistfully. (At one time, *HST* was planned for launch as early as 1983, well before Halley's 1986 perihelion.) "But when it happens, we want to look for deuterium in the comet."

Deuterium, a heavy isotope of hydrogen, is a byproduct of the Big Bang. Chemical processes, such as those that went on as comets formed, can affect the ratio of deuterium (D) to ordinary hydrogen (H), "so getting the D/H ratio is a step in the direction of learning where and under what circumstances comets formed." Brandt points out that deuterium was measured in Halley and that single unexpected result — that the concentration of deuterium was about the same as in the oceans on Earth — has reinforced speculation that the oceans are actually the product of impacts of comets over the 4.6 billion years of Earth's history. Clearly studies of deuterium with *HST* may have striking implications.

Into a Gravitational Well

While many astronomers will be seeking planets with *HST*, an equally enthusiastic group will be looking for black holes. Whether lurking in a binary star system or at the heart of Andromeda or another galaxy, a black hole would represent the culmination of a decades-long search.

Astronomers believe that most, if not all, very massive stars end their lives as black holes. An important search for such "low-mass" black holes, those with masses of a few to a dozen or so times the mass of the Sun, will be conducted by astronomers on the High Speed Photometer science team. The group, led by Robert Bless of the University of Wisconsin, will take advantage of *HST*'s ability to record very rapid brightness changes in stellar sources. Bless plans to monitor several black hole candidates, including the binary systems Cygnus X-1, LMC X-3, GX 339-4, and A0620-00, looking for the fast fluctuations that "could be the dying pulses from blobs of hot gas falling into the black holes."

What about similar blobs falling onto a neutron star? Bless explains that they can differentiate between material falling onto a neutron star, which should "end with a big splash," and matter falling into a black hole, which fades and is no more. Furthermore, if the group detects repeated pulses from inward-spiraling blobs, the repetition rate of the pulses will tell the mass of the black hole. The faster the pulse rate, Bless says, "the lower the mass, because a blob can orbit closer to the black hole before it crosses the event horizon."

Supermassive black holes, as opposed to stellar-mass black holes, may contain the mass of hundreds of millions of Suns. Located in the centers of galaxies, supermassive black holes can nicely account for otherwise incomprehensible phenomena, such as the enormous energy output of quasars. Thus, finding indisputable evidence that they exist — or determining that they do not appear to be present — has major astrophysical implications.

Richard Harms of the Applied Research Corporation, who leads the Faint Object Spectrograph (FOS) science team, says that team members will use both the WF/PC and the FOS "to pin down black holes at the centers of about a dozen galaxies — if they are there." The researchers will use the WF/PC to measure the way brightness changes with distance at the very center of a galaxy and from that learn what the luminosity distribution of the millions of closely packed stars in the galactic core is. If the stars are packed especially tightly toward the center, it would indicate that a small object with great mass — a supermassive black hole — is present.

To verify the WF/PC results, Harms will take spectra of the galaxies with the FOS at many different locations within "the inner one arcsecond or so." Then he'll analyze the absorption lines in the spectra to get a rotation curve. This is "a mathematical description of how the rotational velocities of stars increase toward the center of a galactic system," Harms explains. Because stars orbit the center of a galaxy under the influence of gravity, Harms says that the rotation curve "will give us a reliable probe of how much matter is inside a given radius." That should once again point toward a supermassive black hole, if one is there.

An Exciting Year Ahead

Extrasolar planets, the expansion rate of the universe, the last gasps of matter vanishing into a black hole — these are a few of the things *HST* will look for. But there is much, much more. The *HST* astrometry team, led by William Jefferys of the University of Texas, will use the Fine Guidance Sensors to obtain precise positions for many stars and galaxies and thus help establish an accurate reference frame around the sky. Several investigations will seek to learn the nature of quasars and their host galaxies. Images made with the Faint Object Camera, which was developed by the European Space Agency, will be searched for evidence of interstellar matter condensing into protostars. Even astronomers who emphatically oppose the establishment view that the large redshifts of quasars are due to the expansion of the universe will have a chance to validate their contentions with *HST*.

The list of research projects goes on and on. It's nearly impossible to present a truly representative selection of either *HST*'s research programs or the astronomers who are planning them. Books are being written on the subject and even they may not be comprehensive. And as many of the observing programs are executed later this year, the Space Telescope Science Institute will be issuing a call for new proposals for the next year's worth of deep-searching observations, a procedure that will be repeated in each of the next fifteen years. From our celestial backyard to the farthest range of *HST*'s powerful mirror, the next several years promise a host of exciting discoveries. ☐

Stephen P. Maran is senior staff scientist in the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center. Next month he will be honored as the A. Dixon Johnson Lecturer in Scientific Communications at Pennsylvania State University.

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U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$89.50**
Illuminated reticle eyepiece system	**$99.50**

Guider for Hasselblad **$350,** Mamiya 645 **$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$185,** Mamiya 645 **$159**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)	**add $99.95**

Adapter for Hasselblad **$195,** Mamiya **$96**

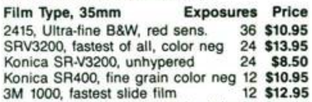
WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector** . **$219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.

Declination motor (state telescope) .. **$99**
NEW Deluxe Digital Qtz. Drive Correc. **$298**



NEW **SRV3200**

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	Exposures	Price
2415, Ultra-fine B&W, red sens.	36	$10.95
SRV3200, fastest of all, color neg	24	$13.95
Konica SR-V3200, unhypered	24	$8.50
Konica SR400, fine grain color neg	12	$10.95
3M 1000, fastest slide film	12	$12.95
Fujichrome RD100, fine grain slide	24	$12.95
D-19 B&W Developer	1 gal.	$6.95

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LUMICON® SKY VECTOR™- *NEW!*

Computer-Controlled Digital Setting Circles, only $498

Sky Vector ™
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STAR
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LUMICON SKY VECTOR™ computer, showing digital readout of coordinates, and easy-to-use controls. Shaft encoders are included (not shown). The coordinates are for Minkowski 1-79, a 13th mag. planetary nebula.

The LUMICON SKY VECTOR™ is a computer-controlled digital setting circle system. It represents a breakthrough in both computer performance and low price. To find an object just move the telescope until the coordinates of the SKY VECTOR™ match those of the object desired.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

Incredibly Smart!
thus
Incredibly Easy!

- Digital right ascension readout to 1 minute of R.A.
- Digital decl. readout to 10 arc-min
- NEW! High resolution encoders
- Motor drive ***not required!***
- Polar alignment ***not required!***
- Just sight two stars!

The computer's sophisticated program (over 3000 lines of code) determines **everything** from an initial sighting of just two stars!

- **No need** to enter latitude, longitude, sidereal time, date, etc.
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080. The computer automatically knows the difference.
- Uses Epoch 2000.0, 1975.0 or 1950.0 coordinates.
- Light weight, only 2 oz. permits mounting near the eyepiece, if desired. Only 2.6"x2.6"x1".
- 9V Battery lasts many nights.

LUMICON SKY VECTOR™ for Meade 2080,2120,C-8,C-11, *(Specify)*	**$498**
For Celestron-14 .. **$575.** For any alt-azimuth (Dobsonian) telescope	**$498**
For Coulter Odyssey 8", 10", 13", 17½" *(Specify telescope)*	**$498**
SKY VECTOR KIT. You must supply adapting hardware. For skilled ATM's only	**$449**

Reference catalogues listing coordinates of 1000's of objects

Burnham's *Celestial Handbook*, Vol. I, II, III (Epoch 1950.0)	**$36.85**
The *Revised New General Catalogue* (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II, doubles, variables, deep-sky objects	**$29.95**

NEW FROM LUMICON

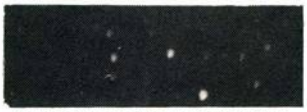
NGC
SKY VECTOR™
$750

- Advanced version of the LUMICON SKY VECTOR™ with over 8000 object deep-sky memory
- All 7730 revised NGC objects
- All 110 Messier objects
- 365 double & multiple stars
- For alt-azimuth, equatorial, fork mounts
- High resolution encoders
- Identifies unknown objects
- Directs telescopes to desired objects by providing real-time angular distance to object
- Provides size, magnitude, coordinates, and visual description of all 8000 objects in memory

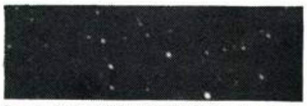
PLEASE SPECIFY TELESCOPE TYPE

LUMICON NGC SKY VECTOR for Meade 2080/2120	**$750**
NGC SKY VECTOR for C-8, C-11	**$750**
LUMICON NGC SKY VECTOR for Celestron-14	**$825**
NGC SKY VECTOR for Coulter Odyssey 8, 10, 13, 17½"	**$750**
NGC SKY VECTOR Kit, you supply hardware	**$709**
NGC SKY VECTOR Kit for equatorial mounts	**$795**

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5



Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

MEADE® TELESCOPES

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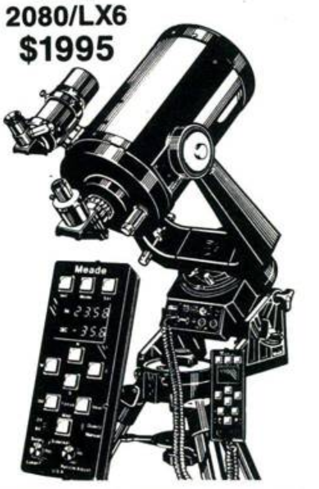
LUMICON ACCESSORIES

2080/LX6 8" f/6 .. $1995
2120/LX6 10" f/6 . $2499

Digital readout system for 2080/2120/LX6	**$399**
8200 object memory CAT computer	**$999**

NEW 2080/LX6 $1995



Meade Model 2080/LX6: The most advanced Schmidt-Cassegrain telescope available today. The hand-held electronic command center controls all telescope functions, and has digital coordinate readout available as an option. The f/6.3 optics yield 2½x shorter exposures in astrophotography.

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Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89;** 32mm **$109**
Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**
Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

SCHMIDT-CASSEGRAIN

2080 Original w/tripod, MCOG	**$1089**
2080 Original 8" f/10 w/tripod	**$999**
2080/LX3, 8" f/10 w/MCOG	**$1450**
2080/LX5, 8" f/10 w/MCOG	**$1650**
2120/LX5, 10" f/10 w/MCOG	**$2095**
2120/LX3, 10" f/10 w/MCOG	**$1895**
2045D 4" f/10 w/motor drive	**$695**
#39 declination motor for LX5	**$109**
#38 (LX3) or #38A (2045) dec. mtr.	**$99**
Dew shield - essential! 8" **$65;** 10"	**$98**
LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
MTS-SN8, 8" f/4 w/LX3 drive, MCOG	**$1048**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

NEWTONIAN

Model 826C 8" f/6 w/motor, 2" focuser	**$975**
Model DS-10A, 10" f/4.5 w/mtr., 2" focus.	**$975**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser	**$1975**
Model DS-16A w/Sealmaster ball bearings for photography	**$2195**
8X50mm finderscope w/brackets for DS-10 or DS-16	**$109**

1.5x, 1.8x MULTIPLIER LENS

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. It multiplies by 1.5x without the included extension tube. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.5x/1.8x multiplier lens	**$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $49.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser	**$59.50**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion low profile focuser	**$129.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle version, w/star diagonal	**$195**
1¼" Deluxe right-angle Super-Finder*	**$279**
25mm Cross-hair 1¼" eyepiece (12X)	**$29**
*1¼" Star Diag. **$32**, 2" Star Diag., silver,	**$159**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	**$30.00**
2" adapter for Takahashi E-130, 160	**$59.50**

SPACE ASTRONOMY IN THE 1990S

BOUND FOR JUPITER

After years of waiting, the *Galileo* space probe has been launched toward Jupiter. On the way it will explore Venus, Earth, and an asteroid.

by Joel Harris

As 5.4 million pounds of thrust from its engines and boosters drove *Atlantis* skyward, teams of tired, anxious, frustrated engineers and planetary scientists applauded, cheered, and then got misty eyed. For them this launch bore a decade's work as it rose first into an azure sky and then into the blackness of space. Thus *Galileo* began its six-year flight toward the gas giant world Jupiter on October 18, 1989.

Delays had plagued the *Galileo* mission for years. Funding threats, major hardware changes, and the *Challenger* explosion nearly grounded the mission. Days before launch the threat of a late-season hurricane and protesters concerned about *Galileo*'s nuclear-powered RTGs threatened delays beyond the 1989 launch window. The San Francisco earthquake, centered near a crucial Air Force tracking center, was also cause for alarm. Yet *Galileo* flew.

Before the successful October 18 launch, it was difficult for anyone connected with the program to feel secure. Dr. Lennard Fisk, associate administrator for NASA's Office of Space Science and Applications, said at a news conference just prior to the launch that it was a case of "do or die" — if the shuttle or the astronauts failed to launch the spacecraft toward Jupiter this time, the *Galileo* project would face cancellation.

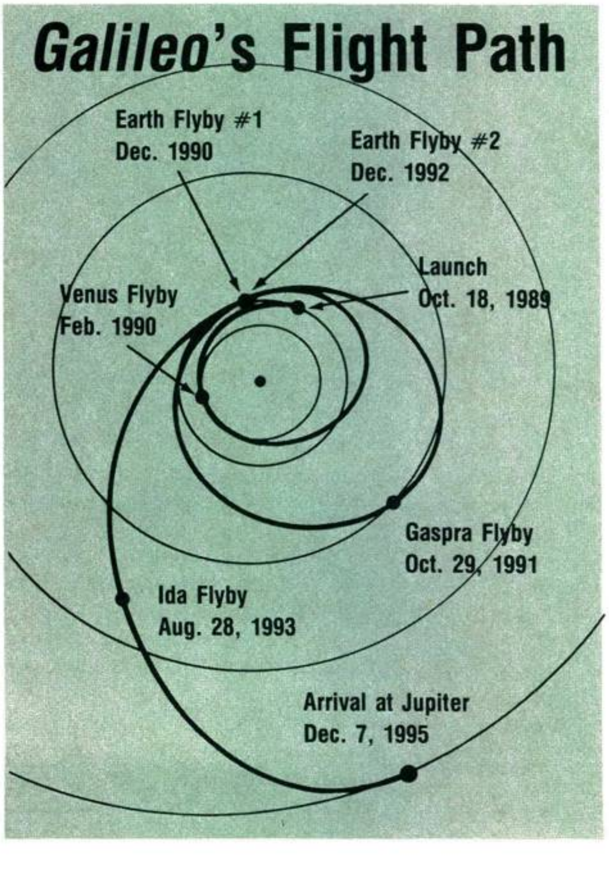
Launch Day

Four miles from the launch pad at the Kennedy press site, reporters and photographers from around the world waited. The Italian media — drawn by a spacecraft bearing the name of Galileo Galilei — were present. The BBC had a radio crew doing a live broadcast to London, with planetary scientist Clark Chapman providing commentary. Reporters from major science periodicals, daily newspapers that cover space science, all four television networks, and other media flocked to Kennedy to view the liftoff.

On the day of the launch, tension was palpable in the air. The launch one day before had been scrubbed, because Launch Director Robert Sieck decided that rain showers over the Kennedy return-to-launch landing strip posed a threat. The outlook for the 18th was even worse, with a 40 percent chance of weather constraints delaying the launch. When a brief hold at T minus 5 minutes was lifted and the weather was deemed acceptable both in Florida and at the Zaragosa, Spain, transatlantic abort landing site, gentle applause rippled through the press grandstand. The clock counted down to zero.

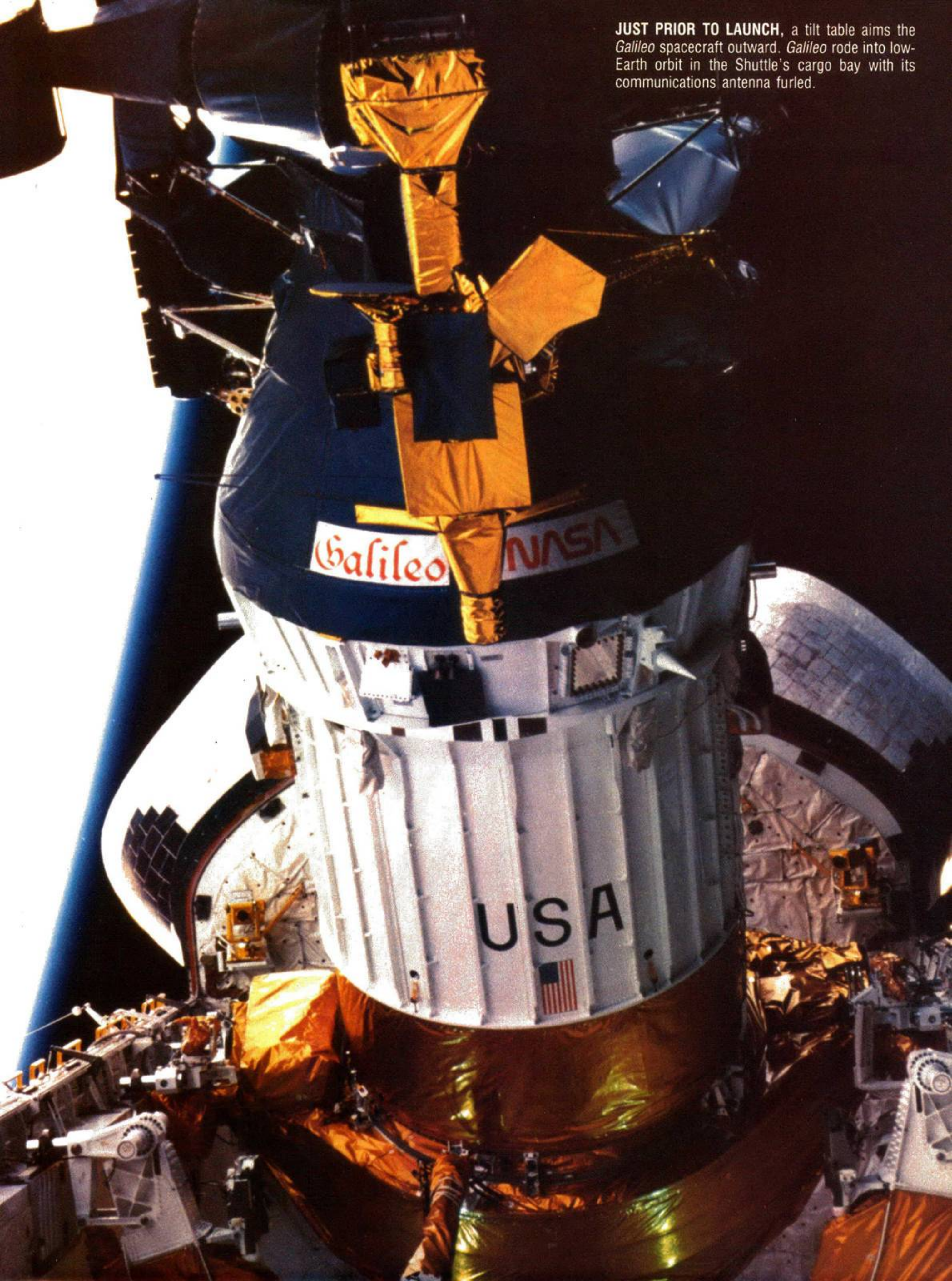
As solid rocket motors flamed into life, usually staid reporters started clapping, yelling, shouting, and jumping up and down as *Atlantis* rose on an 850-foot-long pillar of fire. Like distant thunder, the sonic shock wave of the engines built to a jarring roar, only adding to the goose-bump-raising exhilaration of seeing *Galileo* take to the air.

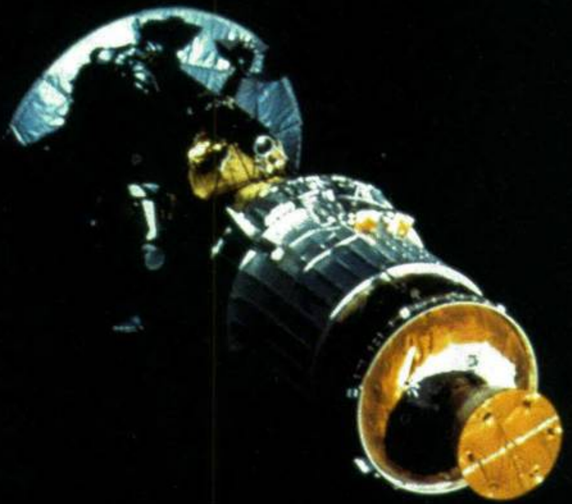
By early evening the crowd at Kennedy Space Center had thinned considerably. Thunderstorms had boiled up to the north of the Space Center and there was a high-wind warning in effect. But *Atlantis* safely orbited 161 nautical miles overhead, nearing the coast of Texas over Brownsville, headed out over the Gulf of Mexico. At the able coaxing of Shannon Lucid, mission specialist 1 on this flight, large springs nudged *Galileo* away from its tilt table at a leisurely half-meter per second. The capcom at Johnson Space Center reported over NASA



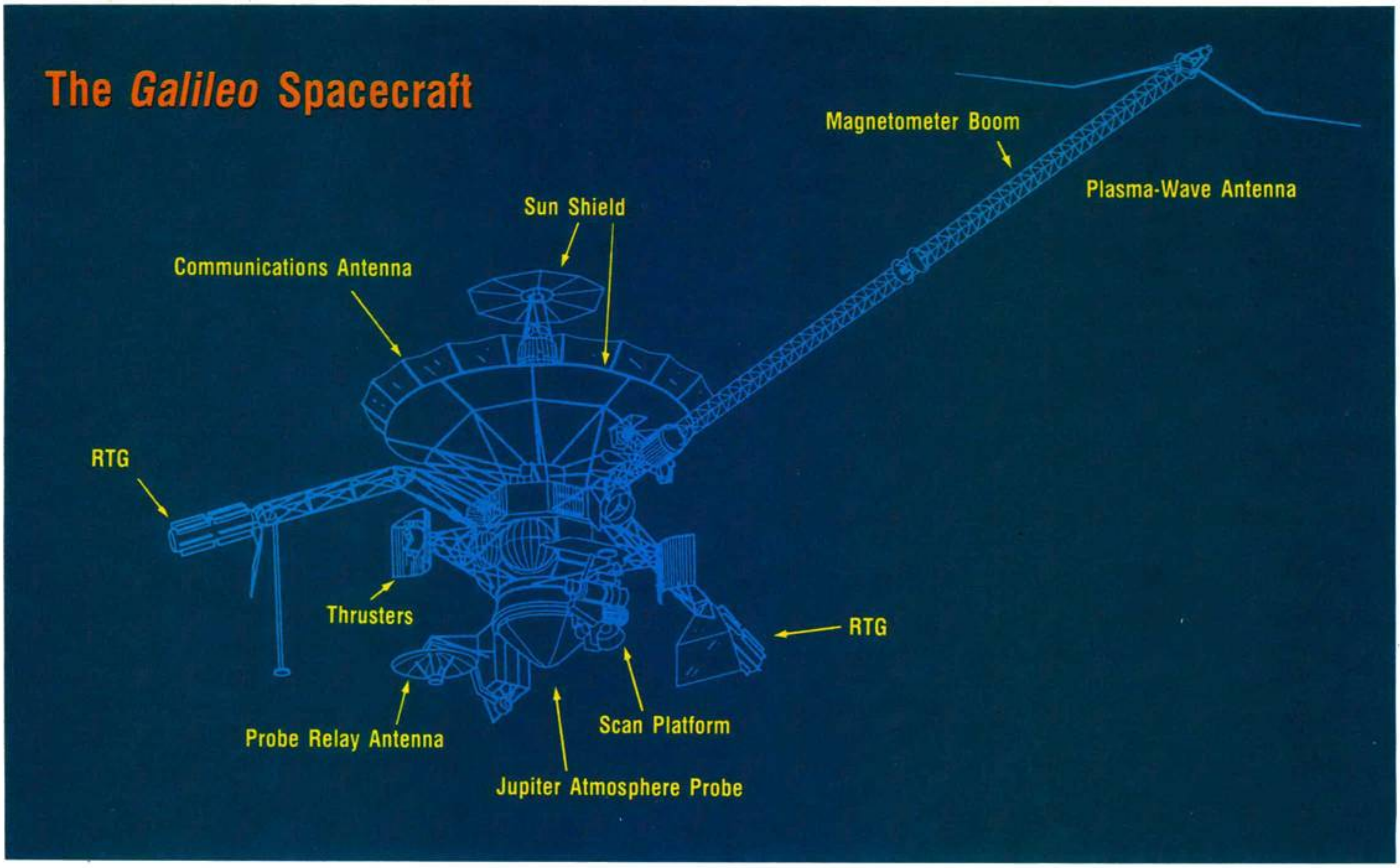
***Galileo*'s Flight Path**

JUST PRIOR TO LAUNCH, a tilt table aims the *Galileo* spacecraft outward. *Galileo* rode into low-Earth orbit in the Shuttle's cargo bay with its communications antenna furled.





FREE AT LAST, *Galileo* drifts a safe distance from the Shuttle before firing its IUS booster to speed it toward a rendezvous with the planet Venus.



Select TV that telemetry showed the IUS/Galileo stack had been released from the payload bay and was drifting away from *Atlantis*.

On the ground the thunderstorm struck the press center. Rain, lightning, and thunder nearly overwhelmed the events transpiring in orbit above. The din grew so loud that reporters in the press dome were forced to seek the quiet of the rest rooms to capture the crew's words as they released *Galileo* on its long voyage. At 7:13 p.m. EDT, Commander Don Williams announced from the flight deck of Atlantis, "*Galileo* is on its way to another world, at the hands of the best flight controllers in this world. Fly safely. . . ." *Atlantis* and the astronaut crew had not let anyone down. Their job was now done. Slightly over an hour later, as *Atlantis* flew over the island of Borneo, capcom relayed to the shuttle crew: "*Atlantis*, Houston. Sunnyvale tracking now confirms *Galileo* is on a hyperbolic trajectory and has now left the Earth's gravitational field."

Get Ready and Wait

Reaching Jupiter in working order is still far from certain for *Galileo*. To reach Jupiter, the spacecraft must survive a trip through the high temperatures in the inner solar system that it was not designed to fly through and execute two precise near-Earth gravity-assist flybys, all while functioning as a dual-spin spacecraft of a type that has never been tested in space.

Another concern was *Galileo*'s age. During the three-and-a-half year stand down following the *Challenger* accident in 1986, the main probe parachute and the flight-rated lithium sulfide batteries in the probe were replaced because of concern they would become too old to function. "All the hardware concerns have been dealt with," said Dick Spehalski, project manager for *Galileo*.

The twin radioisotope thermoelectric generators — the plutonium dioxide-fueled devices that provoked antinuclear protesters — were not changed, even though their power output is declining. Instead, *Galileo*'s power use was reduced and an additional thirty small radioactive heater units were added to the orbiter to reduce its need for electricity on the long flight to Jupiter.

Earlier changes in flight hardware had already taken a toll by lengthening the flight to Jupiter. Following the *Challenger* accident, NASA deemed the Centaur liquid hydrogen/liquid oxygen upper stage too risky to fly on *Atlantis*. *Galileo* was forced into using the original Boeing inertial upper stage — a reliable rocket motor, but far less powerful than the Centaur.

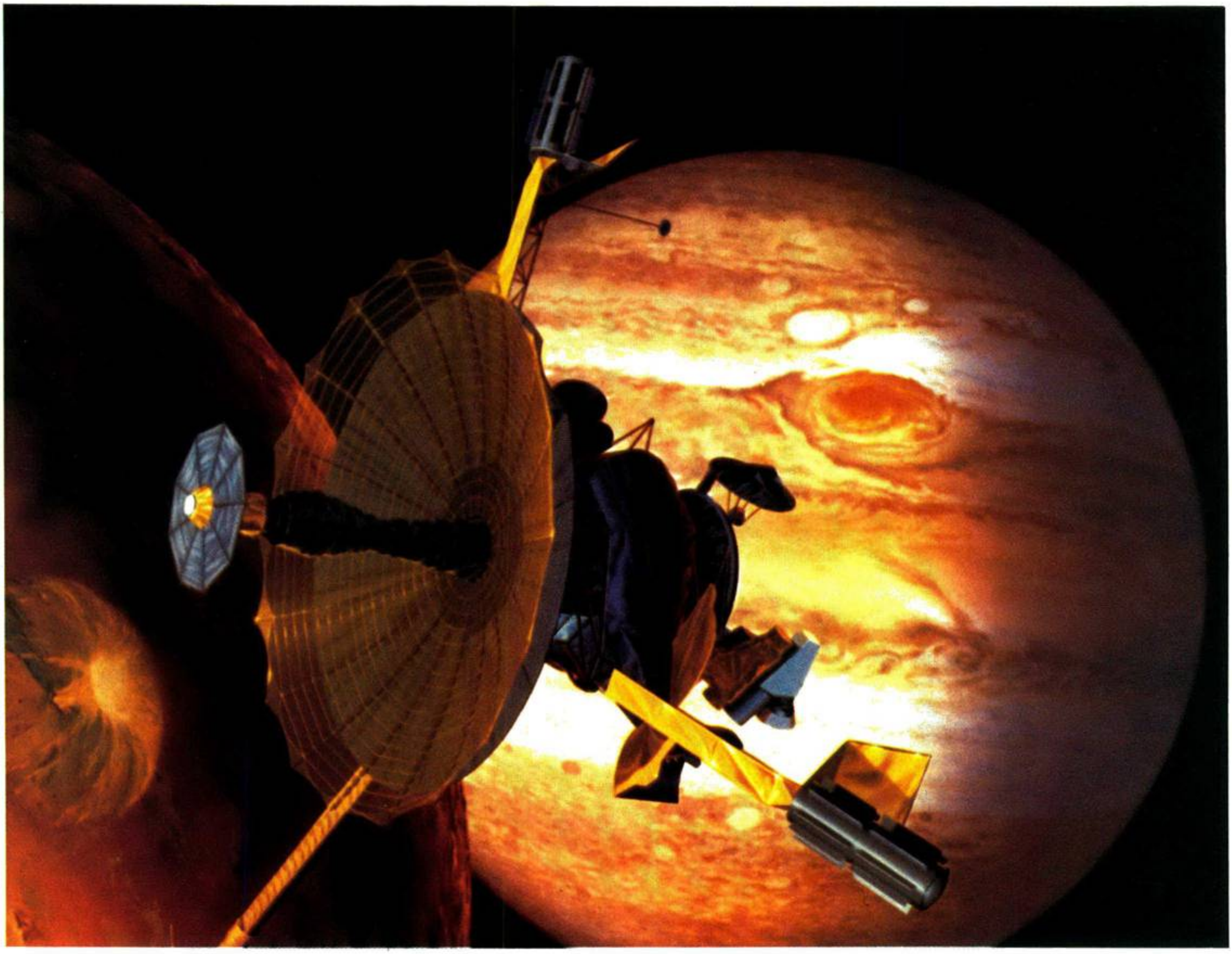
As flight engineers struggled to find a way to send the 2,700-kilogram craft to Jupiter on a weak rocket, mission designer/orbital mechanic Roger Diehl at JPL created the Venus-Earth-Earth Gravity Assist, or VEEGA, mission. This roundabout road will guide *Galileo* to its objective with almost no loss of scientific data — just a long journey before reaching Jupiter.

Even the launch delay while *Atlantis* sat on the pad may have taken its toll on the mission. Because the spacecraft's trajectory will be changed slightly to compensate for its six-day-late departure from Earth, fuel margins are reduced, and the scientists may get two fewer Jovian satellite encounters. The delay might also scrub a flyby of the asteroid Ida, again because of diminished fuel margins.

Yet even against such losses, *Galileo* stands to become a watershed program in the effort to learn more about the very early history and development of our solar system.

Science on *Galileo*

Galileo was built to accomplish three scientific objectives at Jupiter: determine the chemical composi-



AFTER ARRIVING AT JUPITER in December 1995, *Galileo* will combine a gravity assist from Io and the power of its thrusters to go into orbit around Jupiter.

tion, and structure of the atmosphere; characterize the geology, morphology, and physical state of the Galilean satellites; and determine the composition, structure, and nature of the Jovian magnetosphere. "Since the *Voyager* flybys in 1979," said *Galileo* Project Scientist Torrance Johnson, "we have been constructing models on very little data. Everything has been extrapolated from this limited base of information.

"We should see some very new things with *Galileo*," said Johnson. "For example, we really know almost nothing about Europa. The results following the encounters with the satellites are likely to be mind blowing. In addition, our view of the Jovian ring system is likely to be revised totally."

Although the lengthy cruise to Jupiter is risky, the complex VEEGA trajectory presents many unique science opportunities. Shortly after Trans-Venus Injection, the spacecraft's ultraviolet spectrometer will be aimed at Earth to search for "mini-comets." In a highly controversial theory envisioned by Louis Frank of the University of Iowa, as many as twenty of these small icy bodies impact Earth's atmosphere each minute.

When *Galileo* approaches from Venus' night side, it will look for lightning discharges within Venusian cloud formations. Because *Galileo*'s large communications antenna must remain furled until *Galileo* is far from the Sun, the Venus data will be recorded for playback eight months later.

When the spacecraft heads back toward Earth in December 1990, it will approach our Moon from its far side. As it flies over the lunar north pole, it will search for lunar ice, which is theorized to lie frozen in shadows where the Sun never shines. On its second Earth flyby in December 1992, *Galileo* will make a time-lapse movie of the diurnal rotation of our planet and the motion of our Moon as it moves around the Earth in its monthly orbit. Suggested by astronomer Carl Sagan, one of *Galileo*'s interdisciplinary investigators, this plan makes use of an unusual space science photo opportunity.

Depending on its fuel supply, *Galileo* may also encounter Gaspra and Ida, two main-belt asteroids. These small bodies could provide scientists with new, fundamental data about the character of early planetary accretion.

After a decade of delays and waiting, *Galileo* is now on its way to Jupiter. It faces a long trip, roundabout and risky, yet the first steps have now been taken. The spacecraft has left Earth's gravitational field and is now coasting toward Venus. The perennial hanger queen has begun her journey at long last. ☐

Announcing 15 New Product Models From JMI!

NEW TOLL-FREE ORDER LINE

NGC-MAX

Next Generation Computer Maximum

DSC-MAX

Digital Setting Circles Maximum

Twice the resolution of most competing units!

Gone are the days of gaudy encoders and exhaustive initializing!
Available for 2080/2120, C-11, C-14, 2045, B&L4000, Dynamax 8

Get all the advantages of the latest in computer assisted astronomy - without the large, cumbersome encoders and confusing displays of yesterday.

A sleek design with a simple, easy to understand display. Be up and running in minutes with no need to enter the date and time, or latitude and longitude. Beginner or advanced, the NGC-MAX can take you to the limits of astronomy. You do need to know at least two stars to get started. Alignment can be done on any two of 8,205 objects* in the database.

Throughout your viewing session, NGC-MAX shows the current Right Ascension and Declination of your telescope on its variable brightness, sixteen character LED display.

Your Astro Tutor — unplugs in seconds and you can take it anywhere. Learn about the universe in your spare time. The information is scrolled across the screen.

Your Astro Guide — With arrows you and your telescope are pointed through the universe.

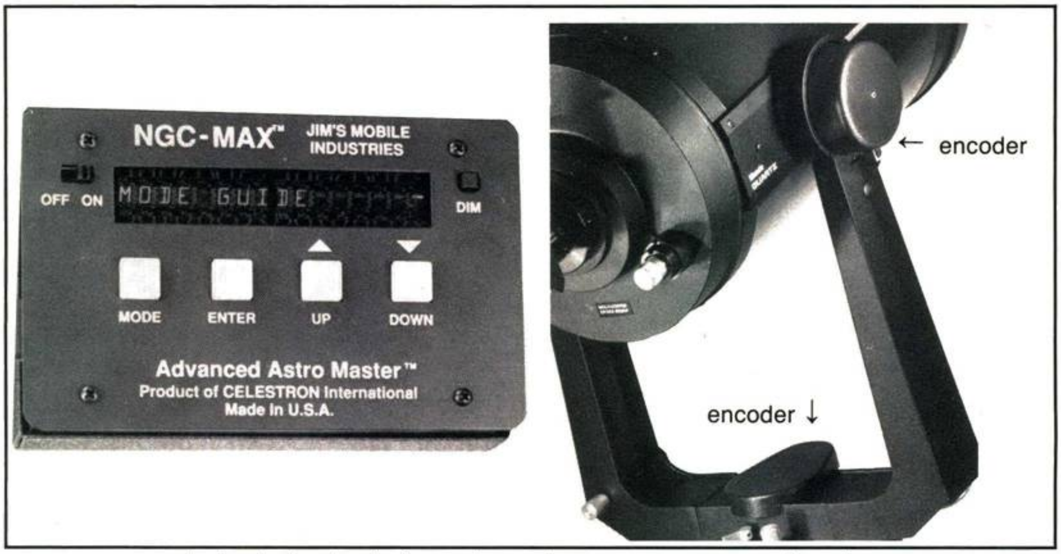
Your Information Center — If you are looking at an object you cannot identify or just want information about, NGC-MAX will scroll the object's coordinates, magnitude, type, and when available, common name, constellation, and additional description. You may also request this information on any object in the database at any time — without having to move the telescope. The low current drain of its high-tech circuitry allows 25 hours of operation from a single 9V battery.

NEW ROM RELEASE now permits entry of 25 user-defined objects! Add planets, comets asteroids and other favorite objects. **New Polar Align Mode** helps the user obtain a perfect polar alignment (not necessary to operation).

DSC-MAX High resolution, computer-controlled digital setting circles for most popular telescopes. Real-time display of R.A. and Dec. coordinates on eight character, variable brightness, red LED display.

Polar alignment NOT required, no need to enter date and time, or latitude and longitude.

(As with all digital setting circles, the user is required to know, or have reference to, the coordinates of desired objects. Not necessary with the NGC-MAX.)



MODEL NUMBER	R.A. Encoder cover	DEC Encoder cover	Tripod mounted holder	4000 bit resolution	3000 lines of code	Depend. Tele. jack	24 hour timer	Guide Mode	Identify Mode	Internal object database	Polar Align Feature	Catalog Mode	Easy 15-30 min. install.	Available	PRICE	Specially Engineered for these telescopes
DSCLX	X	X	X	X	X	X	X						X	NOW	$499	Meade 2080/2120 LX, 2/3/5/6
DSCGEM			X	X	X	X	X						X	NOW	499	440/2080/2120 GEM
DSC2045	X	X	X	X	X	X	X						X	DEC	499	Meade 2045
DSC4000	X	X		X	X	X	X						X	DEC	499	B&L 4000
DSC8000			X	X	X	X	X						X	DEC	499	B&L 8000/Dynamax 8
DSCC11	X	X	X	X	X	X	X						X	NOW	499	Celestron 11
DSCC14		X	X	X	X	X	X						X	NOW	499	Celestron 14
NGCLX	X	X	X	X	X	X	X	X	X	X	X	X	X	NOW	799	Meade 2080/2120 LX, 2/3/5/6
NGCGEM			X	X	X	X	X	X	X	X	X	X	X	NOW	799	440/2080/2120 GEM
NGC2045	X	X	X	X	X	X	X	X	X	X	X	X	X	DEC	799	Meade 2045
NGC4000	X	X		X	X	X	X	X	X	X	X	X	X	DEC	799	B&L 4000
NGC8000			X	X	X	X	X	X	X	X	X	X	X	DEC	799	B&L 8000/Dynamax 8
NGCC11	X	X	X	X	X	X	X	X	X	X	X	X	X	NOW	799	Celestron 11
NGCC14		X	X	X	X	X	X	X	X	X	X	X	X	NOW	799	Celestron 14
NGCKIT					X	X	X	X	X	X	X	X	X	NOW	725	For the advanced tel maker

We are out to capture the market by providing a better product. The last thing you need is a computer hanging to the side of your telescope with velcro or a broken encoder because it wasn't covered or placed out of the way. We have solved these problems and more. Give us a try. SATISFACTION GUARANTEED *Jim Burr*

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Orion® Sky Explorer 60mm Equatorial Refractor

Perfect First Telescope for the Student of Astronomy

The Orion Sky Explorer is not just a beginner's toy: its sharp, coated optics, and clear, distortion-free eyepieces, plus stable equatorial mount will split inumerable double stars, reveal interesting planetary detail, and rove the mountains of the moon.

Enjoy the bright nebulas like Orion and the Dumbbell, the fabulous Double Cluster in Perseus, the incredible globular clusters M13 or M22, and the colorful double star Albireo, plus thousands of other astronomical delights that are well within its light-gathering reach. There's no limit to your enjoyment: taken to a dark sky site, the Sky Explorer will dazzle you with astronomical pleasures!

The Sky Explorer features a 900mm focal length, 60mm objective doublet with magnesium fluoride coatings, white enameled aluminum tube assembly with integral dew cap and lens shade, 6x30 crosshair finderscope with adjustable mounting bracket, right-angle star diagonal, two fully-coated .965" Kellner eyepieces: 25mm (36x) and 9mm (100x), equatorial mount with dual setting circles, slow motion controls, adjustable counterweight, hardwood tripod, and accessory tray with light.

#9092 Was $339 ***Now $329*** (10.90)

Orion® 80mm MC Enhanced Giant Binoculars

Fantastic Giant Binoculars for Astronomy and Terrestrial Observation

Orion Enhanced Binoculars are the finest series of large-aperture binoculars available. All models feature superior unitized 'BCF' body design, BAK-4 high refractive index prisms, soft rubber eyecups and a pair of contoured eyequards. Every pair laser collimated. Include heavy-duty tripod mounting adapter, soft rubber eyeguards, attractive and durable hard carrying case, lens caps and straps.

11x80 MC Giants

Especially designed for astronomical observation from very dark-sky locations and for terrestrial surveillance from very dark locations. Fantastic for observation of the faintest extended nebulas. Field of view, 4.5°. Exit pupil, 7.2mm. Weight, 4 lb. 13 oz.

#9502 Was $369 ***Now $349*** (5.55)

16x80 MC Giants

Especially for observation from moderately dark-sky to suburban locations. 45% greater magnifying power offers spectacular views of nebulas and star clusters. Saturn's rings and Jupiter's moons can be seen clearly and crisply. Field of view, 3.5° Exit pupil, 5.0mm. Weight, 4 lb. 13 oz.

#9496 ***$379*** (5.95)

20x80 MC Giants

Get detailed images of open and globular star clusters, glowing celestial nebulas, galaxies, Saturn's rings, the moons of Jupiter, and the surface of the Moon. Dual 20x optical system resolves detail impossible to see in a spotting scope. Ideal for any home with a view, bird watching, or long distance surveillance. Field of view, 3°. Exit pupil, 4.0mm. Weight, 4 lb. 13 oz.

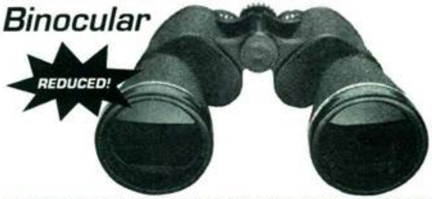
#9498 ***$389*** (5.95)

Orion® Little Giant™ 9x63 Roof Prism Binocular

With the optimum ratio of power to diameter, the Little Giant has a 7mm exit pupil, the largest for the dark-adapted human eye and a huge 6° field-of-view. Roof-prism design gives excellent contrast and sharpness at the center of the field, although edge sharpness is not as good as porro prism binoculars. Perfectly aligned and calibrated to meet strict optical standards. Black ribbed rubber armoring. Only 2.8 lbs. Includes sturdy hard carrying case, fold-down rubber eyecups, straps, and lens caps.

#9500 ***$199*** (4.19)

Orion® Sky Explorer™ Mini Deep Sky 8x56 Binocular



Extra large 56mm objective lenses gather plenty of light for viewing faint celestial objects, yet the binoculars are only slightly larger than standard size 7x50's. Remarkably lightweight, so you'll use them for all kinds of viewing: astronomy, sporting events, hiking, sight-seeing, and general daytime exploring. 6°field-of-view. Wt. 2.1 lbs. Includes lens caps, straps, and deluxe hard case.

#9504 Was $149 ***Now $139*** (3.79)

ORION
TELESCOPE CENTER

California Earthquake: Business As Usual

Orion sustained NO DAMAGE to inventory or equipment in the recent earthquake.

Ad Code FMA, P.O. Box 1158, Santa Cruz, CA 95061

Orion® Explorer Series 1.25" Eyepieces

Remarkably Affordable Multi-Coated Parfocal Eyepieces With Great Performance!

Orion Orthoscopic eyepieces provide remarkably high performance approaching that of premium oculars at less than half the cost. The Kellners offer surprisingly good performance, especially in the longer focal lengths, and give observers on a limited budget access to a complete range of quality eyepieces at a very low cost.

All are precisely machined to fit 1.25" eyepiece holders, threaded for filters, and internally blackened to prevent stray light reflections. The parfocal design minimizes re-focusing when changing between eyepieces in the series. Anti-reflective Multi Coatings, (unusual for eyepieces in these price ranges), maximize light transmission, increase contrast, and minimize ghost images from bright objects far better than standard optical coatings.

1.25" Kellner Eyepieces

6mm, 40° field #8536; *9mm, 40° field* #8538
12mm, 40° field #8540; *18mm, 54° field* #8508
25mm, 40° field #8510; *40mm, 30° field* #8512

$33.95 ea. (1.89)

1.25" Orthoscopic Eyepieces

5mm, 44° field #8500, *7mm, 44° field* #8502
9mm, 44° field #8504, *12.5mm, 40° field* #8506
18mm, 45° field #8524, *25mm, 41° field* #8526

$49.95 ea. (1.89)

Quality, Affordable 2x Orion® Barlow Lens

This 1.25" barlow uses a full 24mm diameter lens, 50% bigger than many standard barlows. It is fully coated on all air-to-glass surfaces for maximum brightness and contrast. Works with all 1.25" eyepieces and is ideal for compound telescopes and reflectors.

#8744 **$39.95** (1.89)

Dew Remover Gun

Evaporate dew instantly from the surface of your corrector plate, mirrors or lenses! Moisture dissipates quickly with this 12V DC, 156 watt warm air gun. Plugs into any automotive cigarette lighter receptacle. Does not smear or scratch like other cleaning methods. The Dew Remover Gun blows them all away! Not for use with Orion Porta-Pac Batteries.

#5601 **$17.95** (2.09)

Field Tripod Tote Bags

Designed for standard tripod and wedge combinations of SC telescopes up to 10" aperture, these bags provide protection and convenience. Made of 100% Cordura nylon with heavy-duty double stitching, wide nylon-webbing straps and handles. Zippered pockets hold star charts and hardware.

Deluxe Field Tripod Tote Bag
Heavily padded, large girth allows storage of wedge without changing polar alignment. Padded insert separates wedge from tripod. Double-stitched zippered closure. Blue with black straps.

#15096 **$79.95** (4.28)

Economy Tote & Storage Bag
Identical to the deluxe model, but without the padding. With this model, there's no need to remove the wedge. Handy nylon drawstring closure with positive catch. Black with black carrying straps.

#15095 **$34.95** (3.59)

Orion® Universal Camera Adapter

For 1.25" Eyepiece Holders

Combination eyepiece projection tube and prime focus adapter for refractors and reflectors. Use with T-ring to match your 35mm camera.

#5264 **$34.95** (1.89)

Orion TeleVista 60mm Altazimuth Refractor

Affordable Telescope for Enjoying Astronomical and Earthly Delights

Orion's 60mm altazimuth refractor is the perfect first step for the astronomer or naturalist. We took a good, long look at department store telescopes in the same price range, assessed their shortcomings, then designed the TeleVista. This fine refractor has a stable altazimuth mount and quality optics that have impressed even sophisticated and experienced amateur astronomers. What it doesn't have is any of the useless, gimmicky accessories so often included with "toy" telescopes. Your first impression will be as exciting as your enjoyment after years of use.

How did we do it? We started by using precision optical glass instead of acrylic lenses, we increased the field of view with more advanced ocular designs, and installed a fine, fully-coated 60mm objective doublet. A quality coated right-angle prism star diagonal provides upright, mirror-reversed viewing with less light loss than most corrected-image Amici diagonal prisms. We eliminated the tiny "450 power" eyepieces and blurry barlow lens that can't provide clear, resolved optical images, and the cheap prism diagonal that dims the image making it virtually unusable for astronomy!

Then we went to work on the mount: We added a smooth slow-motion control for azimuth (left-right) and a stabilizing arm with vernier for altitude (up-down), enabling easy terrestrial viewing and tracking of sky objects. We chose a sturdy, attractive adjustable-height wooden tripod for comfortable viewing height and balance, even on non-level ground.

By day, the TeleVista is a powerful aid to nature observation, watching boats on the water, or birding. By night, casual and beginning astronomers will discover a miraculous world of lunar landscapes, the celestial ballet of Jupiter and its moons, the rings around Saturn, and the phases of Venus. The larger globular clusters, the star clouds of Sagittarius, the double star of Mizar and Alcor: all these objects may be enjoyed with the two high-quality coated Kellner eyepieces provided, giving 28x and 78x. For easy finding, you also get a 5x24 crosshair achromatic finderscope with adjustable dual-ring mounting bracket.

A User Reports: "I assumed that your 60mm scope was just for kids, but when I saw the moon's shiny face at an Orion Telescope Viewing Night, I just had to have one for myself! I appreciate the extreme clarity and magnification for looking out at the scenery and birds, giving a much closer view than my binoculars. I've also enjoyed the recent total lunar eclipse, and have entertained my family and neighbors with excellent views of Saturn. Your scope gives a much better image than my grandson's department store telescope."

The TeleVista includes adjustable hardwood tripod, rack-and-pinion focuser, right-angle diagonal prism, 5x24 achromatic finderscope, 25mm .965" Kellner eyepiece (28x) and 9mm .965" Kellner eyepiece (78x)

#9091 Was $199 **Now $169** (8.85)

Orion® UltraBlock™ SkyGlow™ Light Pollution Filters

The World's Finest Filters for Severe Light Pollution!

If you observe from sites where light pollution levels are high, Orion UltraBlock SkyGlow filters can give you darker skies than you ever imagined. Observation of emission and planetary nebulas is even possible from areas where they are invisible without a filter. UltraBlock SkyGlow filters block ALL forms of light pollution, including both narrow-band mercury and sodium vapor lighting and broadband light pollution sources. UltraBlock SkyGlow filters reject pollution from incandescent and fluorescent lighting, the type of pollution wide-band filters can't stop. If your skies are heavily polluted, bring high-contrast views into reach with a SkyGlow UltraBlock filter. Order yours today under our no-risk 30-day money-back guarantee.

1.25" UltraBlock Filter	#5654 **$77.50** (1.89)
SC UltraBlock Filter	#5656 **$119** (2.19)

Orion® Premium Off-Axis Guider

Multi-Coated for Peak Performance!

The Off-Axis Guider is the preferred accessory for long-exposure astrophotography with Meade and Celestron 4", 8", 10", 11", and 14" Schmidt-Cassegrain telescopes. It fits between the camera T-ring and the telescope, allowing observation of a guide star while the camera is taking a photograph.

Precision slip-ring threads to fit the rear cell of the telescope for easy rotation when selecting a guide star. Utilizes a separate, adjustable prism cell in case the guider is knocked out of alignment. Requires a T-ring.

#5144 **$59.95** (1.89)

Orion® Color Filters

For 1.25" Eyepieces

Veteran astronomers are convinced that solar system observations are dramatically improved by Orion colored filters. For visual use, thread one into the barrel of any standard eyepiece. For planetary and lunar photography, Schmidt-Cassegrain owners can attach the filter to the eyepiece inside the tele-extender. Can also be threaded directly into a universal camera adapter.

Basic Set of 4 Filters 1.25"
Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5514 Was $44.95 **Now $39.95** (2.19)

Expansion Set of 4 for 1.25"
Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.

#5516 Was $44.95 **Now $39.95** (2.19)

Deluxe Set of 8 for 1.25"
Includes all the filters in our basic and expansion filter sets.

#5517 Was $79 **Now $74.95** (2.79)

Deluxe Metal-Clad Accessory Case

Keep your eyepieces, drive control, camera, and telescope attachments perfectly safe and clean. Special diced foam insert can be custom-tailored to your exact requirements. Attractive silver cases are of strong metal-clad construction with reinforced corners and edges. Beveled closure forms a moisture and dust resistant seal. Twin latches with key locks give extra security. Heavy duty handle. Available in two convenient sizes. You'll be amazed at how much they can hold!

Regular - 16"x12"x6-1/2", wt. 6 lbs.	#5920 **$49.95** (5.09)
Large - 19-1/2"x12"x6-1/2", wt. 8 lbs.	#5921 **$64.95** (5.92)

How to Order

- Call & charge to Visa or MasterCard, or send check.
- Please mention **Key Code FMA001** when ordering.
- U.S. and Canada orders only.
- Shipping & handling charges for UPS Ground or U.S. Mail are listed in (parentheses) after each price.
- California residents add 6% sales tax (Santa Clara County 7%).

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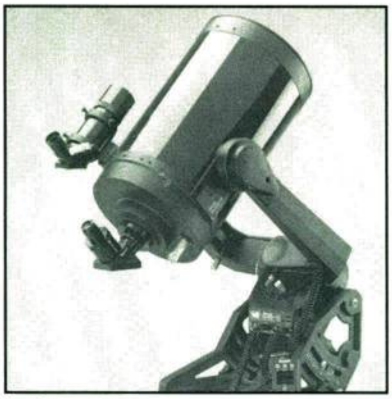
LARGEST, MOST COMPLETE OPTICAL SUPERMARKET IN THE WORLD

CELESTRON Superb Optics

ULTIMA 11
Celestron's newest complete telescope system features an 11" 2800mm f/10 optical tube assembly with Starbright coatings. Standard accessories include: heavy-duty fork arms with handles, heavy-duty wedge with tray, built-in cordless power supply, Byers worm gear drive, quartz-locked electronic drive, new deluxe fitted carrying case, 30mm and 17mm 1-1/4" Plossls, anti-vibration footpads, 2" diagonal with 1-1/4" adapter, counterweights, and more. **$3199 complete**

First Scope 80	**$ 489**
SP-C102	**1099**
SP-C102F	**2099**
C4.5	**489**
Classic 8 w/Starbright	**899**
Powerstar 4	**1499**
Ultima 8	**1699**
C-14 complete	**7899**
Compustar 8	**3199**
Compustar 11	**6299**
Compustar 14	**10,399**
C-90 Rubber-Multi-coated	**449**
Basic C-90	**369**



Meade The Leader's Edge

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56mm 2"	**$ 169**
13.8 S.W.	**119**
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4.7 U.W.	**129**
6.7 U.W.	**155**
8.8 U.W.	**185**
14 U.W.	**219**
#140 Barlow	**73**
2" Star Diagonal	**139**

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#323 Refractor	**469**
#228 Brass	**499**
#314 Brass	**899**
97E	**359**
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2080 LX6	**1759**
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Superwedge	**add 325**
CAT	**889**
CAT RS-232	**999**
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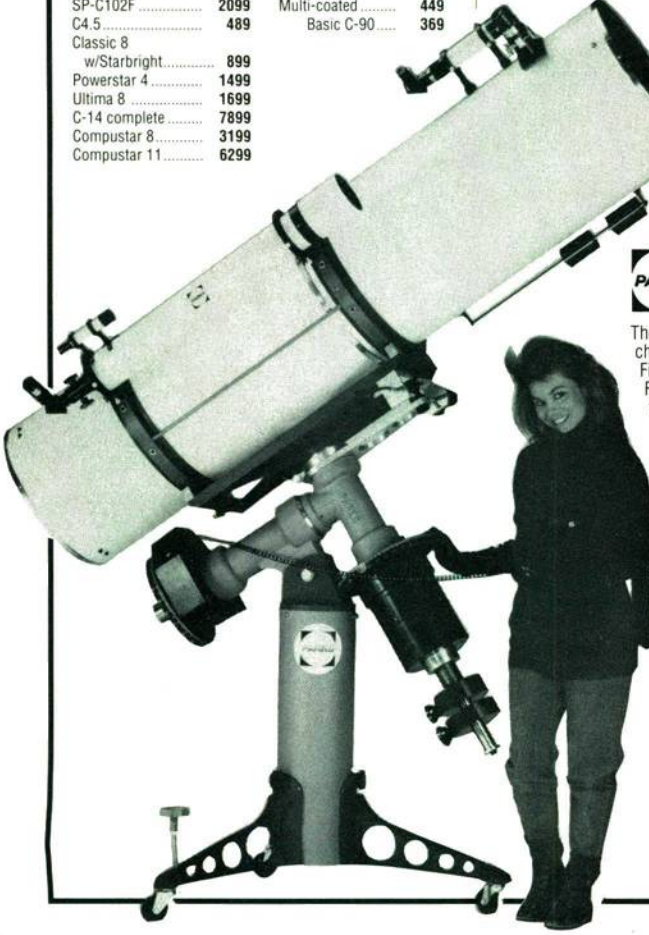

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Unsurpassed Quality

The professional and amateurs choice for guaranteed quality. Finest components throughout. Full thickness optics, fiberglass tubes and precision German equatorial mounts. New state-of-the-art electronic clock drive with dual-axis drive corrector is standard on the Superior and Observatory series and optional for the Precision series. Complete drive corrector upgradable circuitry available for Precision series clock drives.

6" f/6 or f/8 Precision
List $1400 Now **$799**
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10" f/5 Superior
List $4400 Now **$2599**
12 1/2 f/5 Superior
List $5500 Now **$3599**
12 1/2 f/5 Observatory
List $13,000 Now **$7500**
16" f/5 Observatory
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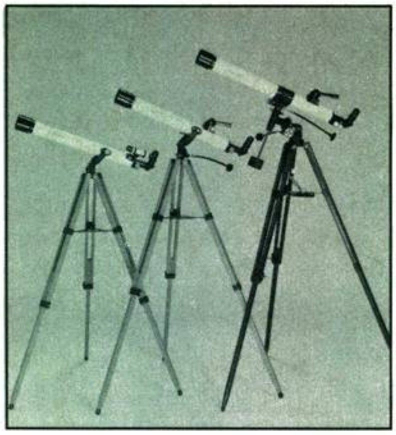
Other sizes available.



PARKS PRT SERIES – For the serious beginner

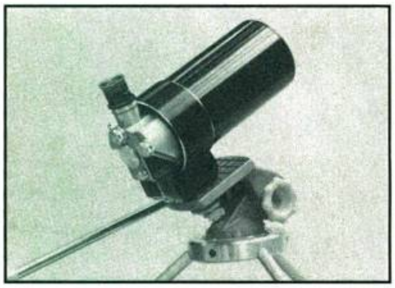
Enjoy the rings of Saturn, the belts and moons of Jupiter, resolve double stars and study the craters of the moon in stunning detail. Unlike department store telescopes, all Parks 60mm PRT Series include 1.25" eyepieces which are of higher quality than the smaller .96" eyepieces. The 1.25" eyepiece system renders brighter, sharper images and longer eye relief, fully coated acromat objective lens, metal tubes. Lifetime guarantee. Use them for astronomy, land and photography.

PRT-1 700mm focal length, includes finderscope, multicoated 25mm Kellner eyepiece, star diagonal, adjustable wooden tripod, and lens caps. List price $400. Sale Price **$279**.

PRT-2 Same as PRT-1, also includes a built-in focusable finderscope, and slow motion controls. List price $525. Sale Price **$379**.

PRT-46 900mm focal length, includes equatorial mount with slow motion controls and setting circles (which allows you to dial-in celestial objects). Add a motor drive for automatic tracking or astrophotography. List price $800. Sale Price **$499**.

Recommended accessories- 6mm, 12mm Kellners, set of 4 photo-visual filters, camera attachments. (see Parks accessory section)



QUESTAR - "THE WORLD'S FINEST OPTICS"

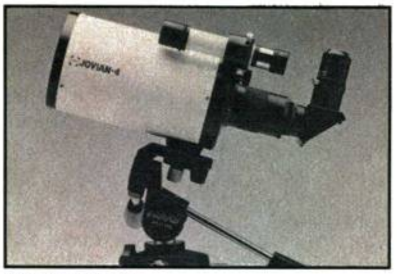
These "jewel-like" instruments are light weight, but deliver performance unmatched by many larger scopes. Built-in barlow and finderscope, superb workmanship and user-friendly.

The standard Questar 3 1/2 includes: 24mm and 16mm Brandon eyepieces; camera coupling set; solar filters for telescope and finderscope; lens shade with engraved perpetual star map; fork mount with slow motion controls and motor drive; setting circles; detailed moon map on telescope barrel; velvet lined carry case with door pouches; lens cap and power cord. Now in stock at all Scope City locations.

Standard Questar 3 1/2
with Pyrex mirror - **$2755**
Pyrex plus special coatings - **$3007**
Zerodur mirror plus special coatings - **$3177**

Duplex Questar 3 1/2
with Pyrex mirror - **$3007**
Pyrex plus special coatings - **$3259**
Zerodur mirror plus special coatings - **$3429**

Field Model Questar 3 1/2
with Pyrex mirror - **$1834**
Pyrex plus special coatings - **$2086**
Zerodur mirror plus special coatings - **$2256**
fast focus - **$400** 10x birding finder - **$655**



PARKS JOVIAN 4

"May well be the very best quality telescope on the market for your money today." 4" Schmidt-Cassegrain with superb optics. Includes 25mm 1-1/4" Gold Series eyepiece, star diagonal, multi-coated and enhanced optics, ultra-precise knob-type focuser, finderscope, custom reinforced carrying case, tripod adapter, and lifetime guarantee. List price $1200. Sale Price **$899**.

Parks Deluxe Giant Deep Sky Binoculars

These binoculars are the leading edge in optical design. They feature the newest BPG2-UV multi-coated prisms for the highest possible image quality and maximum light transmission. Ideal for view-homes, land/sea observing, and astronomy. Features: rubber-armoring, central support bridge, lens shade/dew shields, deluxe case, straps, and lens caps. Lifetime warranty. 11x80, 15x80, 20x80, ZCF's List price $650. Sale Price **$399**.

LEITZ/LEICA BINOCULARS

"The best binoculars in the world". Top German binoculars at 1/2 price! Includes a three year, unconditional no-fault warranty. This is in addition to the standard 30 year warranty.

8x20BC	List $ 645.00	Sale **$ 322.50**
10x25 BCA	List $ 705.00	Sale **$ 352.50**
7x35B	List $1140.00	Sale **$ 570.00**
7x35BA	List $1200.00	Sale **$ 600.00**
8x40B	List $1380.00	Sale **$ 690.00**

Prices include instant rebate. Other models available.

JASON

- 7x50 Empire - "precision optics at a moderate price", fast focus, wide angle, fully coated, lifetime warranty.
- 7x50 "20-20" - extended eye relief for eyeglass wearers. Both feature 50mm aperture for extra light gathering plus a 7mm exit pupil for bright, sharp images for stargazing.
- 10x50 "Realtree" - multi-coated, rubber armored, extra wide angle. Your choice **$89**.

TeleVue

"Even better than you imagined"

Renaissance	**$1449**
Genesis	**1449**
Oracle	**799**
Type II NAGLERS	
12mm	**$ 269**
16mm	**295**
20mm	**349**

JIM'S MOBILE QUALITY COMPONENTS

LX Motodec	**$ 76**
LX Motodec	**79**
NGC-Max	**799**
Mototrak II	**229**
Mototrak G	**219**

For more information and prices on Celestron, Meade, Parks, Questar, Leitz/Leica, T.O. Optical, Brandon, TeleVue, Simmons, Bausch & Lomb/Bushnell, Davionx, VE Digitrak, Edmund Scientific, Fujinon, Jason, Jim's Mobile, Kronehof, Lumicon, Swarovski, Swift, Telrad, Zeiss, Steiner, Musser, Minolta and others, including books, charts and astronomical aids, please call or stop by any Scope City location.

PARKS WIDE FIELD 60 TELESCOPE

Compact telescope/telephoto. Fully coated air-spaced 60mm objective lens provides bright sharp images with incredible wide field viewing. Long eye relief, 420mm focal length with standard 1-1/4" 28mm ocular for an ultra-wide 3° field of view. Complete with 1-1/4" star diagonal, 6x30 finderscope, lens caps, and rubber eyepiece cup. Superb Quality. Camera Adaptable. List $500 NOW **$299**.

8" CASSEGRAIN CARRYING CASE

The perfect addition to your 2080 or Classic 8, a replacement for your damaged or missing case, or an upgrade from the original light-duty case. This case features heavy leather handles, reinforced edges and corners, and high-density foam inserts. Accepts all 8" Schmidt-Cassegrain telescope. List price $175 Sale Price **$99** Dimensions 30"x16"x12".

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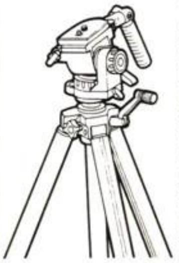

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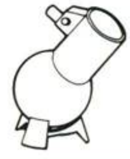

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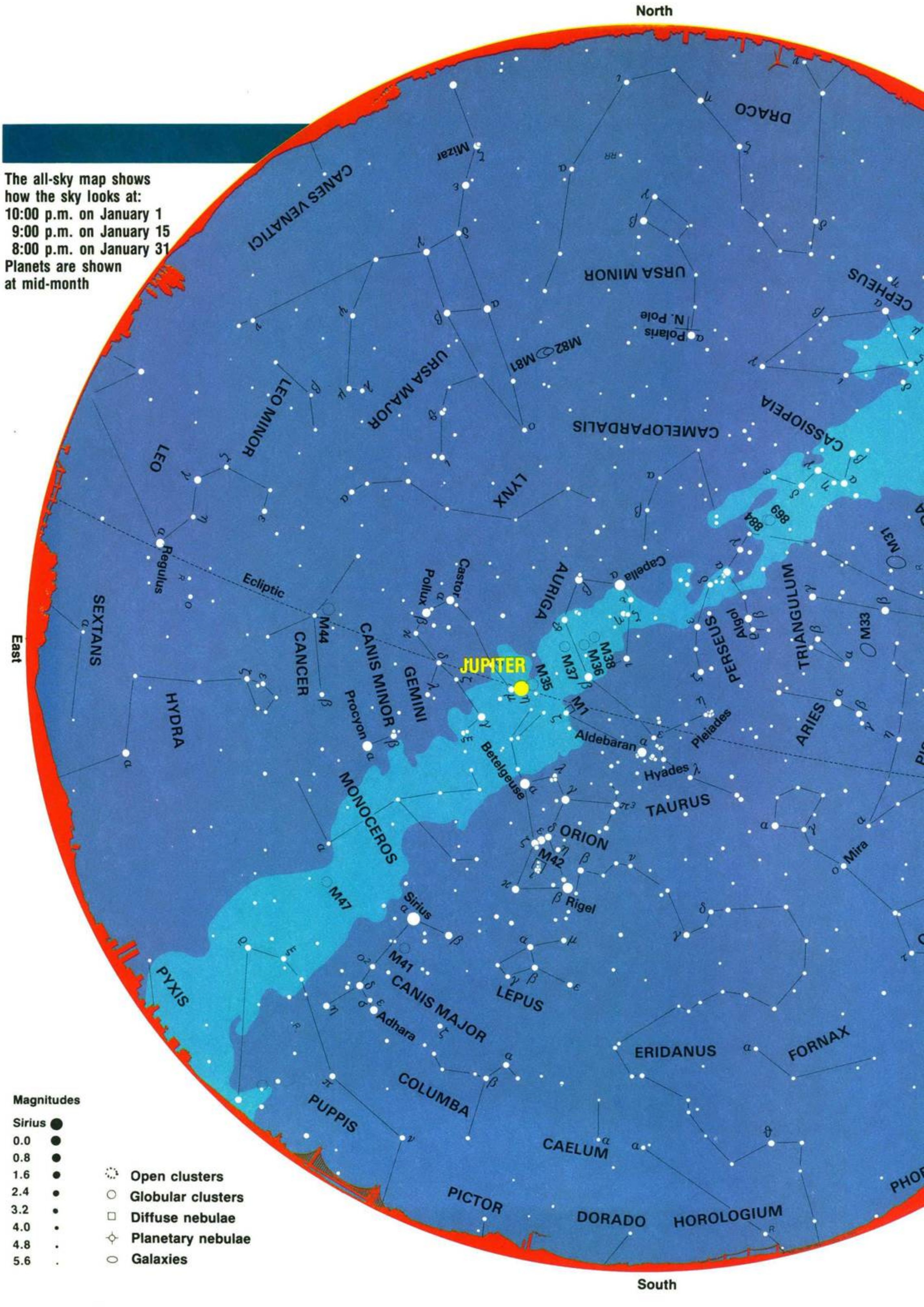
The all-sky map shows
how the sky looks at:
10:00 p.m. on January 1
9:00 p.m. on January 15
8:00 p.m. on January 31
Planets are shown
at mid-month


North
South
East
JUPITER
DRACO
CANES VENATICI
Mizar
URSA MINOR
N. Pole
Polaris
CEPHEUS
URSA MAJOR
M82
M81
LEO MINOR
LEO
Regulus
CAMELOPARDALIS
CASSIOPEIA
LYNX
884
869
M31
Ecliptic
Pollux
Castor
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M44
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GEMINI
M35
M37
M36
M38
PERSEUS
Algol
M1
Pleiades
ARIES
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Procyon
Betelgeuse
Aldebaran
Hyades
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M47
Sirius
M41
CANIS MAJOR
LEPUS
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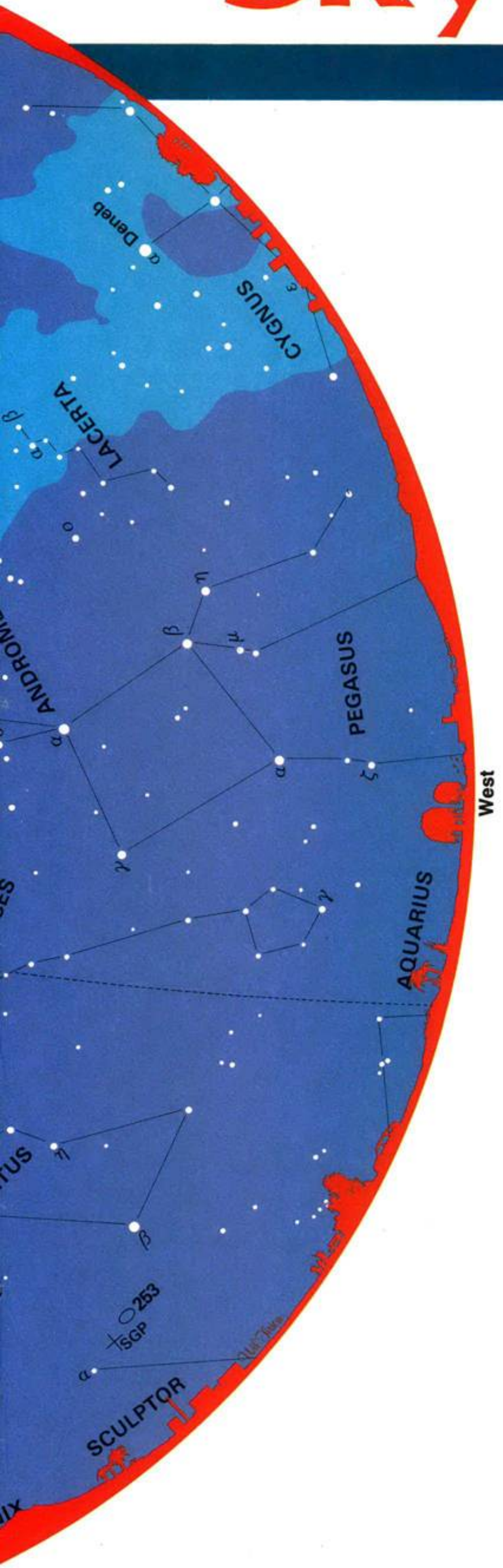
FORNAX
COLUMBA
PUPPIS
CAELUM
PICTOR
DORADO
HOROLOGIUM
PHOE
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

JANUARY 1990



MERCURIAL VENUS

Venus rushes from the evening sky to the morning sky this month. Look for the brightest planet low in the southwest shortly after sunset in early January and in the east-southeast shortly before sunrise in late January.

JUPITER DOMINATES THE NIGHT

Climbing higher in the east with each passing day, Jupiter is the brightest point of light in the sky once darkness falls. Telescope owners can observe the planet's largest disk of the year and monitor the abnormally faint South Equatorial Belt for further changes.

QUADRANTIDS PEAK ON JANUARY 3

The cold-weather Quadrantid meteor shower is one of the year's best. From a dark-sky site you can expect to see forty or more meteors per hour after midnight on the night of January 3/4.

Dates and Times

2 Neptune is in conjunction with the Sun

3 Quadrantid meteor shower peaks

4 First Quarter Moon is at 5:40 a.m. EST
Earth is at perihelion (91.4 million miles from the Sun), noon EST

6 Saturn is in conjunction with the Sun

7 The Moon is at perigee (228,029 miles from Earth), 1:53 p.m. EST

8 Mercury is in inferior conjunction

9 The Moon passes 0.6° north of Ceres, 3 a.m. EST
The Moon passes 4° north of Jupiter, 7 p.m. EST

10 Full Moon is at 11:57 p.m. EST

13 Mercury passes 3° north of Neptune, 4 p.m. EST

18 Last Quarter Moon is at 4:17 p.m. EST
Venus is in inferior conjunction

19 The Moon is at apogee (251,341 miles from Earth), 10:59 a.m. EST

22 The Moon passes 0.3° south of Antares, 3 a.m. EST

23 The Moon passes 4° south of Mars, 10 a.m. EST

24 The Moon passes 5° south of Mercury, 3 p.m. EST

25 The Moon passes 3° south of Saturn, 5 a.m. EST

26 New Moon is at 2:20 p.m. EST; annular solar eclipse

27 Mercury passes 0.8° north of Neptune, 6 p.m. EST

31 Mercury is at greatest western elongation (25°)

Eye on the Sky by Deborah Byrd

VENUS: FROM EVENING STAR TO MORNING STAR

In the first ten days of the new year, Venus stages a dramatic exit from the evening sky. To see Venus then, look shortly after sunset on a clear evening from a site with an unobstructed view of the southwestern horizon.

The dazzling planet appears like an eerie beacon low in the evening twilight, shining at magnitude −4.5. It does not linger there, however, but instead edges closer to the horizon with each succeeding evening. After about the first ten days of the month, Venus lies too near our line of sight to the Sun to be seen with the naked eye.

Yet almost before we have missed it, Venus returns, this time in the morning sky. Watch for the brilliant planet during the last week of January as it rises in the east-southeast shortly before the Sun. Venus will appear surprisingly bright for being located so near the coming dawn.

You can make a game out of the disappearance and reappearance of Venus. Record the date on which you last see Venus with the naked eye and perhaps the date on which you last see it with binoculars or a small telescope. After the inner planet passes between Earth and the Sun on January 18, begin scanning for the planet before dawn. What's the earliest date you can find it in the predawn sky?

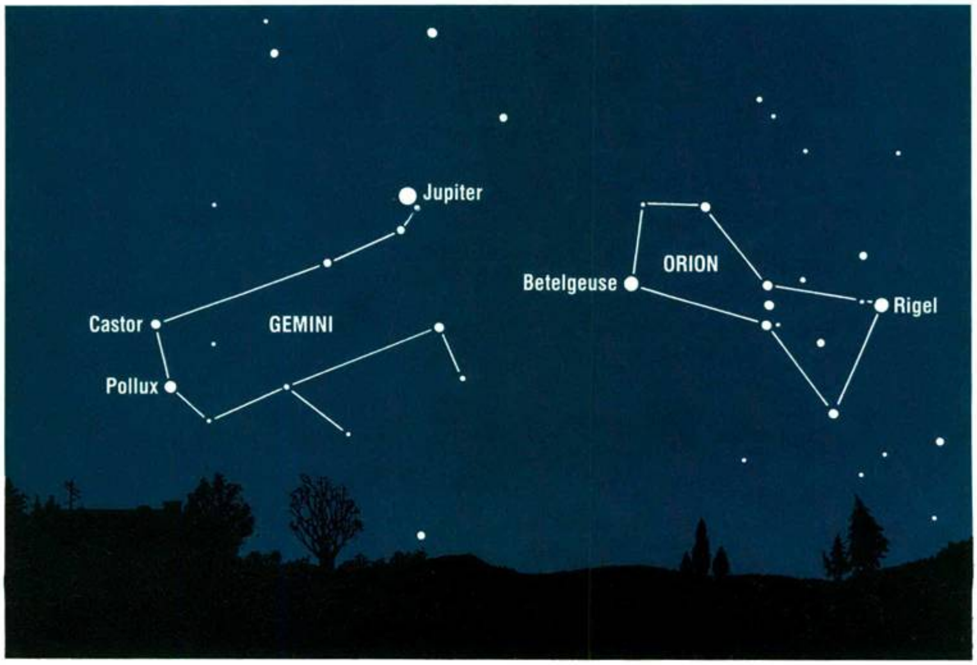
JUPITER BRIGHT IN THE EVENING

Just as Venus regularly passes between the Sun and Earth, Earth passes between the Sun and the outer planets. Earth passed between the Sun and Jupiter in late December, and at that time the giant planet shone at its brightest and appeared opposite the Sun in our sky. In January Jupiter remains very bright, at magnitude −2.7, and lies higher in the sky in the evening hours.

At the beginning of the month, Jupiter appears low in the east after the Sun goes down, reaches its highest point in the sky around local midnight, and sets only minutes before sunrise. As the month progresses, Jupiter appears a bit higher in the east each evening and sets a bit earlier each morning. By the end of January, Jupiter sets a full two hours before the Sun rises.

Because Jupiter is in the sky when darkness falls, it's noticeable to casual stargazers, those who happen to glance up while driving home from work, waiting for a bus, or coming out of a restaurant. Especially after Venus disappears from view, Jupiter dominates the evening sky.

JUPITER SHINES BRIGHTLY in the eastern sky as twilight deepens on January evenings.



CATCH THE QUADRANTIDS

The year's first meteor shower is also one of the best. The Quadrantid shower is often spectacular, producing as many as two hundred or more meteors per hour as recently as 1985. Although in most years the Quadrantids are not that prolific, you can expect to see an average of forty to fifty meteors an hour from a dark-sky site at the shower's peak.

This year the shower peaks on January 3 during the early evening hours for observers in the United States and Canada. Although the shower has a very narrow peak, you're probably better off waiting until after midnight to observe. By then the First Quarter Moon has set, Earth is heading directly into the stream of dust particles that causes the shower, and the shower's radiant, which lies in northeastern Bootes, is higher in the sky.

Quadrantid meteors are characteristically blue in color and they often produce long trains. These factors, along with the large number of meteors possible, make the Quadrantids worth braving the cold weather. Be sure to wear plenty of warm clothing, and take frequent breaks to have something hot to drink, a bite to eat, or just walk around to get your circulation going.

JANUARY'S PLANETS

At magnitude −4.5, Venus is by far the brightest object in the sky besides the Sun and Moon. The planet appears very low in the southwest during the first ten days of the month and then slips into the twilight glare. It is gone from view for about two weeks around inferior conjunction, which occurs on January 18. By the last week in January, Venus has returned to view, this time in the east-southeast shortly before sunrise. It will climb higher in the morning sky over the next two months and appear at its brightest in late February.

If you have binoculars, this is the month to turn them on Venus. If you hold them steadily enough (try bracing your elbows on a car, a fence post, or another convenient object), you should be able to discern that the planet is not round. A telescope reveals Venus to be a very thin and relatively large crescent, which is why its out-of-round shape is now visible in binoculars.

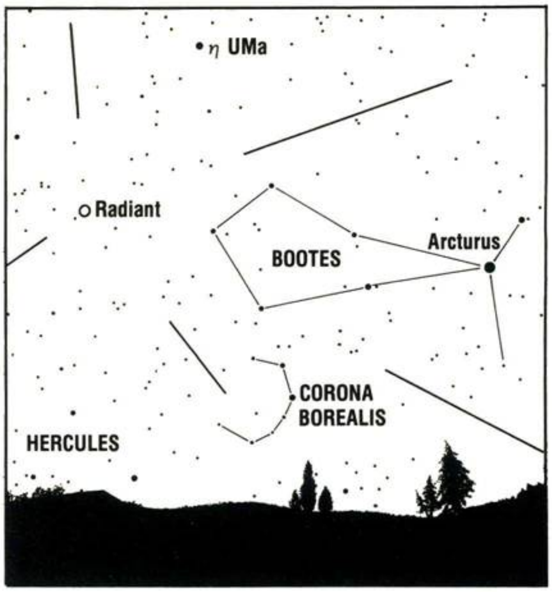
Jupiter, the second brightest planet after Venus, appears low in the east when night falls. The planet spends the entire month near the feet of Gemini, boldly outshining all of the bright winter stars that surround it.

Jupiter shines at magnitude −2.7 in January, its brightest for all of 1990, and it dominates the long winter nights. Although Jupiter is substantially fainter than Venus, it appears more prominent this month. That's because Jupiter gleams against a black sky, while Venus appears against a brightly lit twilight background.

For most of the night, Jupiter is the only visible planet. It isn't until the giant planet gets ready to set that another planet appears, Mars. Mars is an inconspicuous orange-red "star" low in the southeast before dawn. Now far across the solar system from Earth, Mars appears relatively faint at magnitude 1.5. The Red Planet will grow slowly brighter as Earth creeps up on it in its smaller, faster orbit around the Sun, but Mars is destined to remain inconspicuous this winter.

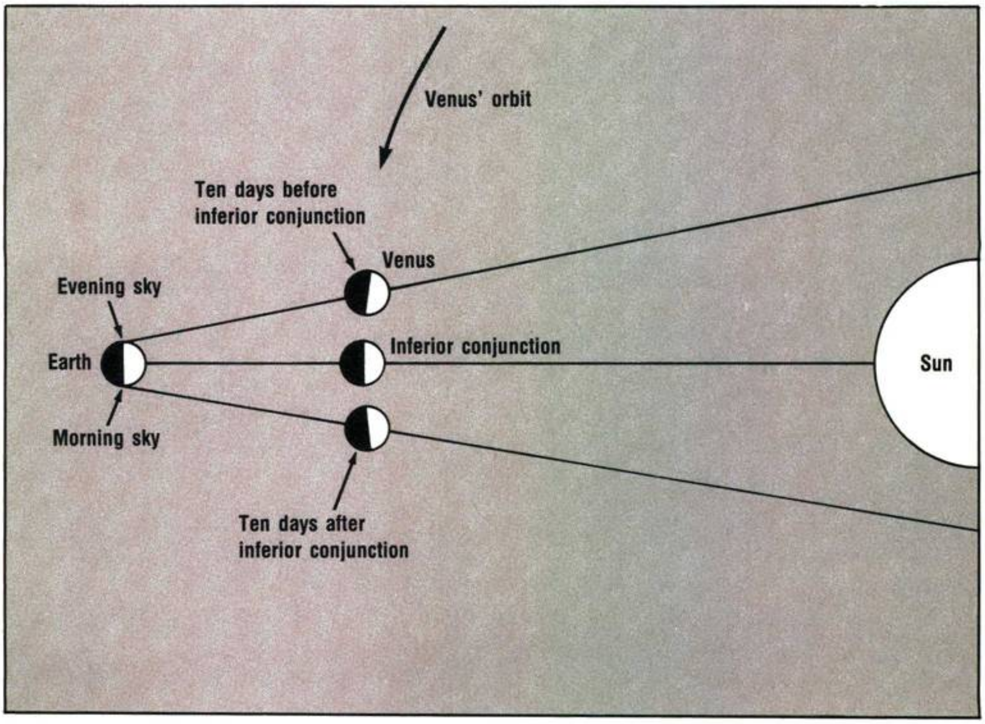
When January opens, the Red Planet lies 5° north of its old rival, the bright star Antares in Scorpius. During the first part of January, Mars moves through the nonzodiacal constellation Ophiuchus. A week before the end of the month, the planet crosses the imaginary boundary into Sagittarius. Mars is joined in the predawn sky by three other bright planets — first Mercury, then Venus, and finally Saturn.

Mercury passes between Earth and the Sun on January 8/9 and afterward moves into the predawn sky. Look for Mercury below and to the left of Mars. This is one of the better apparitions of Mercury this year. At greatest elongation on January 31/February 1, Mercury lies 25° west of the Sun and



BRIGHT BLUE METEORS that leave long-lasting trails are typical of the Quadrantid meteor shower. Look toward the northeast shortly after midnight on the night of January 3/4 for your best view of the shower.

YOU CAN VIEW VENUS in both the morning and evening sky this month. The planet is visible in the evening in early January, disappears from view at mid-month, and returns in the morning in late January.


Venus' orbit
Ten days before inferior conjunction
Venus
Evening sky
Earth
Inferior conjunction
Sun
Morning sky
Ten days after inferior conjunction

shines rather brightly at magnitude −0.1.

Saturn is in conjunction with the Sun — on the opposite side of the solar system as seen from Earth — on January 6 and is out of view until the final week of the month. It then joins the assembly of planets in the southeast before dawn. Like Mars, Mercury, and Venus, Saturn is in Sagittarius, where it shines at magnitude 0.6.

JANUARY'S STARRY SKY

Nearly everyone knows Ursa Major, which has the famous asterism known as the Big Dipper within its boundaries. But ask someone to pick out a recognizable pattern in the winter evening sky and that person will probably pick a short straight line of three stars, the famous Belt of Orion the Hunter.

Orion's Belt is a distinctive pattern that is easy to find in the south each evening. Although the three Belt stars are not exceptionally bright, they're very noticeable because they are close together and about the same brightness.

The Belt stars are famous collectively, but they're not well known as individuals. The westernmost star is named Mintaka; the central star is Alnilam; and the eastern one is Alnitak. All three stars are hot, blue supergiant stars, among the most luminous stars in the Galaxy.

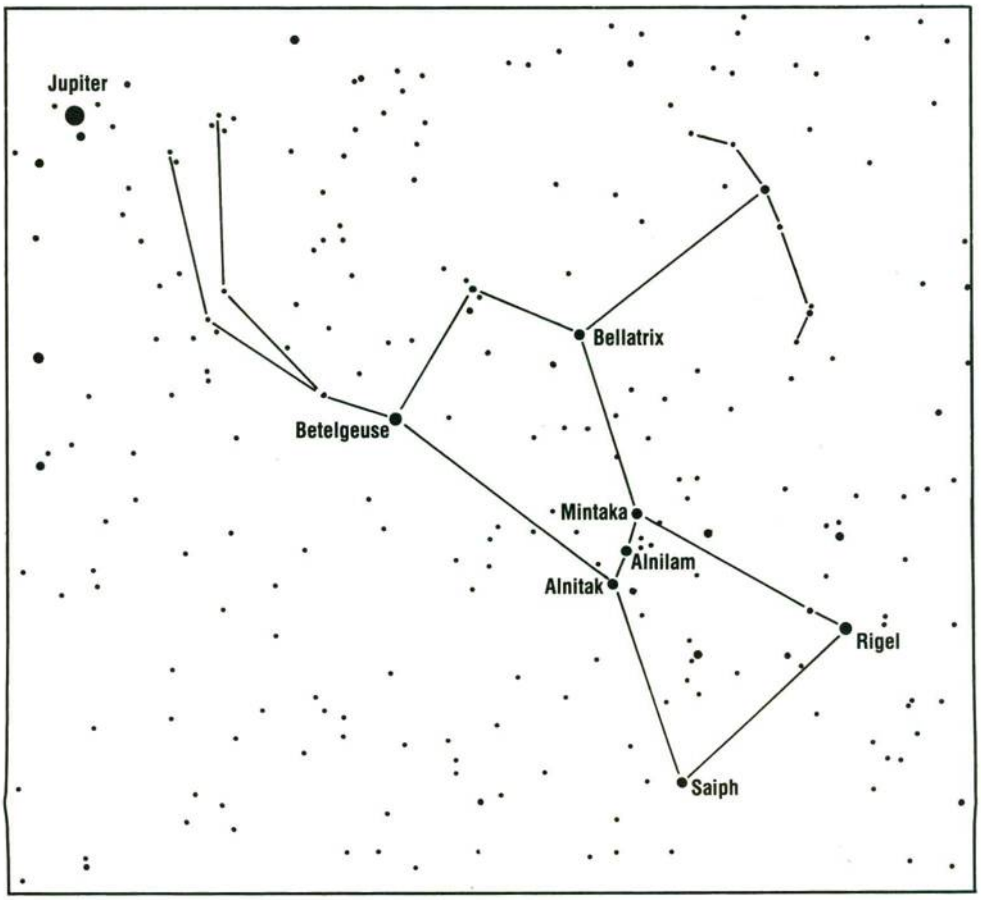
On either side of the Belt and perpendicular to it lie two brighter stars. The reddish one to the north is called Betelgeuse, which represents one of the Hunter's shoulders. The blue-white star south of the belt is Rigel, the Hunter's foot.

In Greek mythology Orion was associated with the forces of goodness and light. According to some legends, he was killed by a scorpion. It's said that because of this ancient rivalry, Scorpius and Orion are never in the sky at the same time.

Other legends explain Orion's death in a different way. Some say he met his fate at the hands of his lover, Artemis, who was goddess of the Moon. One day Artemis' brother Apollo saw Orion swimming by himself in the ocean. Apollo caused a bright patch of light to surround the Hunter and then teased Artemis by saying she'd spent so much time with Orion that she'd lost her skill with a bow and arrow. Apollo challenged his sister to hit the shimmering patch of light and, of course, she did. When Orion's body washed to shore, Artemis was horrified to see her own arrow. She tenderly placed the body of Orion into the darkest spot in the heavens, so that his stars would shine very brightly.

By the way, Orion is one constellation that's worth some effort to see in a very dark sky. If you do, you'll understand why the early stargazers called Orion a hunter. Orion looks very much like a giant man holding an upright club and a curved shield. He's using the shield to fend off the raging bull, Taurus, which is now located directly above him in the sky.

ORION'S BELT is the most distinctive pattern of stars in winter's most prominent constellation, Orion the Hunter. Look for the Hunter's unmistakable shape in the south on January evenings.



KEEP AN EYE ON JUPITER'S ATMOSPHERE

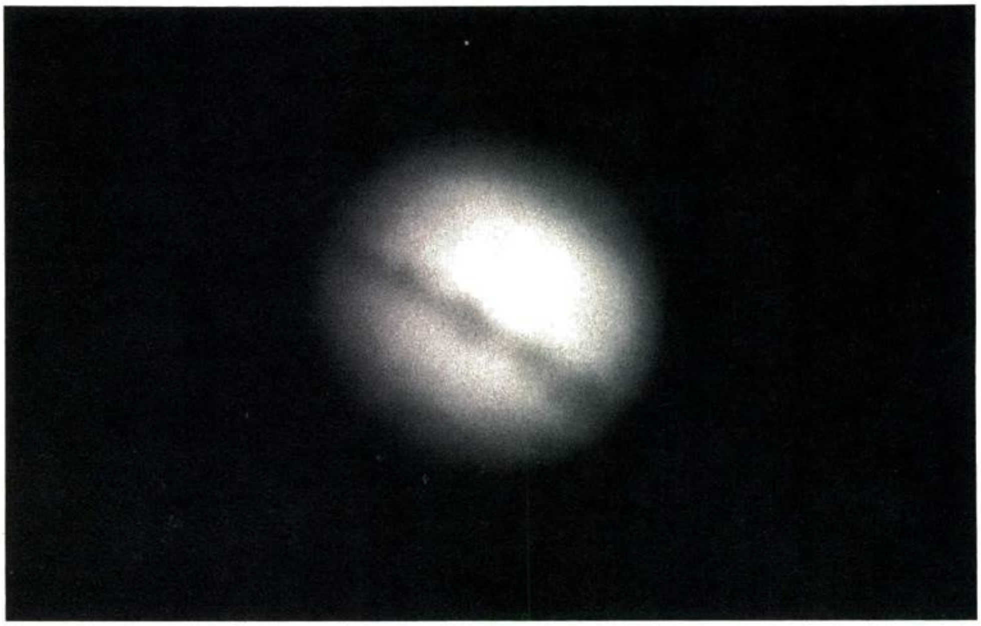
Jupiter, just five days past opposition as the New Year begins, is nearly as large and as bright as it can be. On New Year's Day the giant planet measures a whopping 47″ across its equator and shines at its brightest for 1990, magnitude −2.7. By the end of the month, the planet has lost only 2″ in apparent diameter and has faded just a tenth of a magnitude. But perhaps best of all, now that it is past opposition, Jupiter appears higher in the sky and thus is better placed for telescopic observation in the early evening.

The biggest change in Jupiter's appearance during the past year has been the virtual disappearance of the planet's once prominent South Equatorial Belt. The belt is so faint right now that you'll need all the help you can get to see it. One approach you might try is to use a light-blue filter to increase the contrast between the South Equatorial Belt and the zones on either side of it.

If you have a night of good seeing, try making a sketch or photographing Jupiter. To get the correct proportions of the planet's oval-shaped disk for a sketch, trace over the photograph at right or the diagram of Jupiter on page 65, or use a 70° ellipse template (available at most art-supply stores).

The last two times the South Equatorial Belt faded so dramatically were in 1928 and 1958. At first glance it looks like this may be a cyclical phenomenon with a period of about thirty years, but with only three known occurrences it's much too early to say. If the South Equatorial Belt fades again in 2018 or 2019, however, the idea won't seem so far-fetched.

As you observe Jupiter this month, consider that you're witnessing a remarkable change in a weather system as wide as our planet is large. The fading of the South Equatorial Belt appears to signal a significant change in that region's chemical composition, and no one is sure when it will return to normal. Take advantage of the excellent observing opportunities this month to monitor this event as frequently as you can, and keep alert for signs that the belt is beginning to darken.



JUPITER'S ONCE PROMINENT South Equatorial Belt virtually disappeared in 1989 and no one knows when it will reappear. Photo taken August 26, 1989, by Gregory Terrance.

VENUS AT MORNING, NOON, AND NIGHT

Even though Jupiter should get a large chunk of your observing time this month, Venus is well worth watching as it passes from the evening to the morning sky. Venus is at inferior conjunction — when it lies most nearly between the Sun and Earth — on January 18. Because the planet is both close to Earth and appreciably north of the ecliptic at this time, Venus passes more than 5.5° north of the Sun at inferior conjunction. This unusual geometry makes Venus easy to observe in the evening sky at the beginning of January and almost as easy to observe in the morning sky at the end of January.

Thirty minutes after sunset on New Year's Day, Venus still lies 15° above the southwestern horizon for observers at mid-northern latitudes and appears as a 55″-diameter, 9 percent-lit crescent. Similarly, thirty minutes before sunrise on the last day of the month, Venus has already climbed 11° above the east-southeastern horizon and appears as a 57″-diameter, 6 percent-lit crescent. How late in the month can you observe Venus in the evening sky? How early in the month can you observe it in the morning sky?

The surprising answer is that you may be able to observe Venus all month. Because Venus does not get closer than 5.5° to the Sun at this conjunction, it is far enough away to observe in the daytime, *if* you use the proper equipment and take the necessary precautions to avoid looking directly at the Sun.

To do this you need an equatorially mounted telescope with scrupulously clean optics. If you don't know how to clean the optics yourself, don't; get the help of someone who has done it before and knows what he or she is doing.

Also, you must stop your telescope's aperture down to about 3 inches. If you have a reflector, size and position the stop so that neither the edge of the primary mirror nor the secondary support obstructs the stop's aperture.

OBSERVE VENUS near inferior conjunction with a polar-aligned equatorial telescope offset from the Sun's position. Brian Tkachyk used this technique to photograph the very slender crescent of Venus.

Finally, you need to fashion both an extended dew cap and a dew-cap shade to keep the image of Venus from becoming "washed-out" by the Sun's glare. Get a large piece of black construction paper and cut it into a rectangle approximately 12 inches by 36 inches. (The longer dimension should be twelve times the telescope's stopped-down aperture.) Starting with one of the long edges of the rectangle, roll the paper into a tube 36 inches long that fits snugly over the aperture stop. Seal the outside of the seam with tape, and then tape the dew cap over the aperture stop on your telescope.

For the dew-cap shade take a piece of black construction paper about 12 inches wide by 18 inches long. You should place the shade a few feet in front of the extended dew cap so that the dew cap's end is shaded but the line of sight to Venus is not blocked. One good way to accomplish this is to tape the shade to the tripod head of a camera tripod with the central post extended.

The easiest technique for finding an object such as Venus in the daytime is to use your telescope's setting circles to offset from the Sun's position. To do this you need to align your telescope's polar axis precisely the night before you want to look for Venus. When you are done observing for the night, cover the telescope, making sure not to knock it out of alignment.

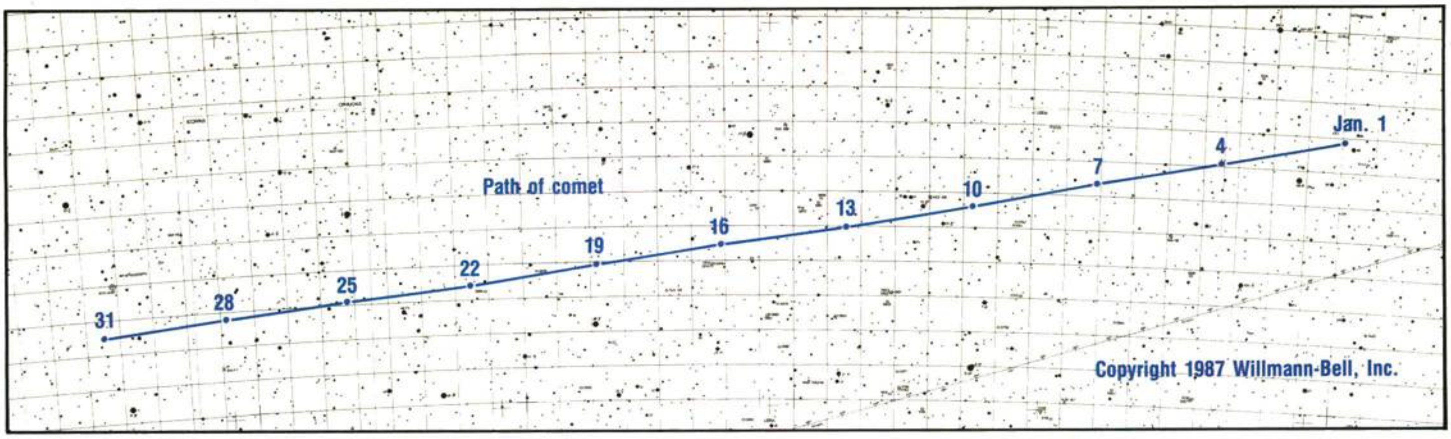
The next day uncover the telescope, securely tape the dust cover onto your finder scope, and place a good over-the-aperture solar filter over the front end of your telescope. Make sure you do this properly — even a quick glance through your telescope at the Sun's unfiltered image can blind you permanently. After the filter is properly positioned, center the Sun in the telescope's field of view. (If you don't have a solar filter, project the Sun's image on a blank white card with your lowest-power eyepiece.) With the Sun's image still centered in the field, set the scope's setting circles to the Sun's position for that date using the data in the table below. Then quickly move the telescope until the setting circles read Venus' position for that date. Remove the solar filter, attach the dew cap, and position the shade so the Sun's light won't enter the dew cap. Finally, put in an eyepiece that gives a magnification of 40x to 60x.

POSITIONS OF VENUS AND THE SUN

	Venus		**Sun**	
Date	**R.A. (2000)**	**Dec.**	**R.A. (2000)**	**Dec.**
Jan. 11	19h32m31s	−21°44′18″	20h16m34s	−15°06′26″
Jan. 12	19h36m51s	−21°34′33″	20h14m13s	−14°59′03″
Jan. 13	19h41m10s	−21°24′23″	20h11m46s	−14°52′14″
Jan. 14	19h45m28s	−21°13′47″	20h09m15s	−14°45′56″
Jan. 15	19h49m46s	−21°02′48″	20h06m41s	−14°40′11″
Jan. 16	19h54m03s	−20°51′24″	20h04m04s	−14°34′59″
Jan. 17	19h58m19s	−20°39′36″	20h01m26s	−14°30′20″
Jan. 18	20h02m35s	−20°27′24″	19h58m47s	−14°26′13″
Jan. 19	20h06m50s	−20°14′50″	19h56m10s	−14°22′38″
Jan. 20	20h11m04s	−20°01′52″	19h53m34s	−14°19′35″
Jan. 21	20h15m18s	−19°48′32″	19h51m01s	−14°17′03″
Jan. 22	20h19m31s	−19°34′50″	19h48m32s	−14°15′02″
Jan. 23	20h23m43s	−19°20′46″	19h46m08s	−14°13′31″
Jan. 24	20h27m54s	−19°06′20″	19h43m49s	−14°12′29″
Jan. 25	20h32m04s	−18°51′33″	19h41m37s	−14°11′55″

Positions are given for 18 UT (1 p.m. EST; noon CST; 11 a.m. MST; and 10 a.m. PST).

If the sky is very transparent, the seeing is steady, and you have



THE PECULIAR COMET Tuttle-Giacobini-Kresak, which has flared by ten magnitudes in the past, rides high in the east-southeast before dawn this month. The comet's positions are shown for the beginning of morning twilight.

a sharp eye, you should be able to see the very large and extremely thin crescent of Venus with the rig I've just described. On the 18th, Venus sports a disk over 1′ in diameter — 30 percent larger than Jupiter's disk — and less than 1 percent lit.

While I'm speaking of daytime observing, I want to give those of you who may have just received your first telescope some important advice. Too many small, imported telescopes still include a "sunglass," a sun filter designed to be threaded into an eyepiece to allow observers to view the Sun safely. However, nothing could be further from the truth.

A typical 60mm refractor intercepts approximately 400 times as much of the Sun's light as the human eye. (Larger telescopes, of course, gather even more light.) The telescope then forms an image of the Sun approximately 6 millimeters in diameter at a point just about 6 millimeters from the field lens of the eyepiece. The "sunglass" is installed at or very near that same point. Thus, the tiny piece of filter glass in the threaded adaptor must absorb all that heat to protect your eye.

As you might guess, these sun filters often crack from being overheated. If you're looking through the telescope when the filter cracks, there's a high probability you'll suffer permanent eye damage. The solution to this problem is simple: *never* use a thread-in eyepiece sunglass to view the Sun. Instead of the sunglass, use either an over-the-aperture sun filter designed for your telescope or project the Sun's image through your lowest-power eyepiece on white paper.

TELESCOPIC PLANETS

Mercury puts in a nice appearance during the last half of January and the first half of February. The elusive planet lies 25° west of the Sun at greatest elongation on January 31/February 1 and is 7° above the southeast horizon forty-five minutes before sunrise. On that date Mercury appears 7″ across and shows a 60 percent-lit gibbous phase.

Mars rises two hours before the Sun in the southeast, but its 4″ disk has little to offer the telescope user. The most interesting event for Mars in January comes on the 29th, when the Red Planet passes 1′ north of the 5th-magnitude star 4 Sagittarii. Use medium to high powers to compare the orange-red glow of Mars to the pure white color of 4 Sagittarii.

Saturn, Uranus, and Neptune are lost in the Sun's glare for most of January and finally come into view in the morning sky during the last week of the month. Because of the usually poor seeing near the horizon, you'll be better off waiting until February to observe these three denizens of the outer solar system with your telescope.

COMETS FOR THE TELESCOPE

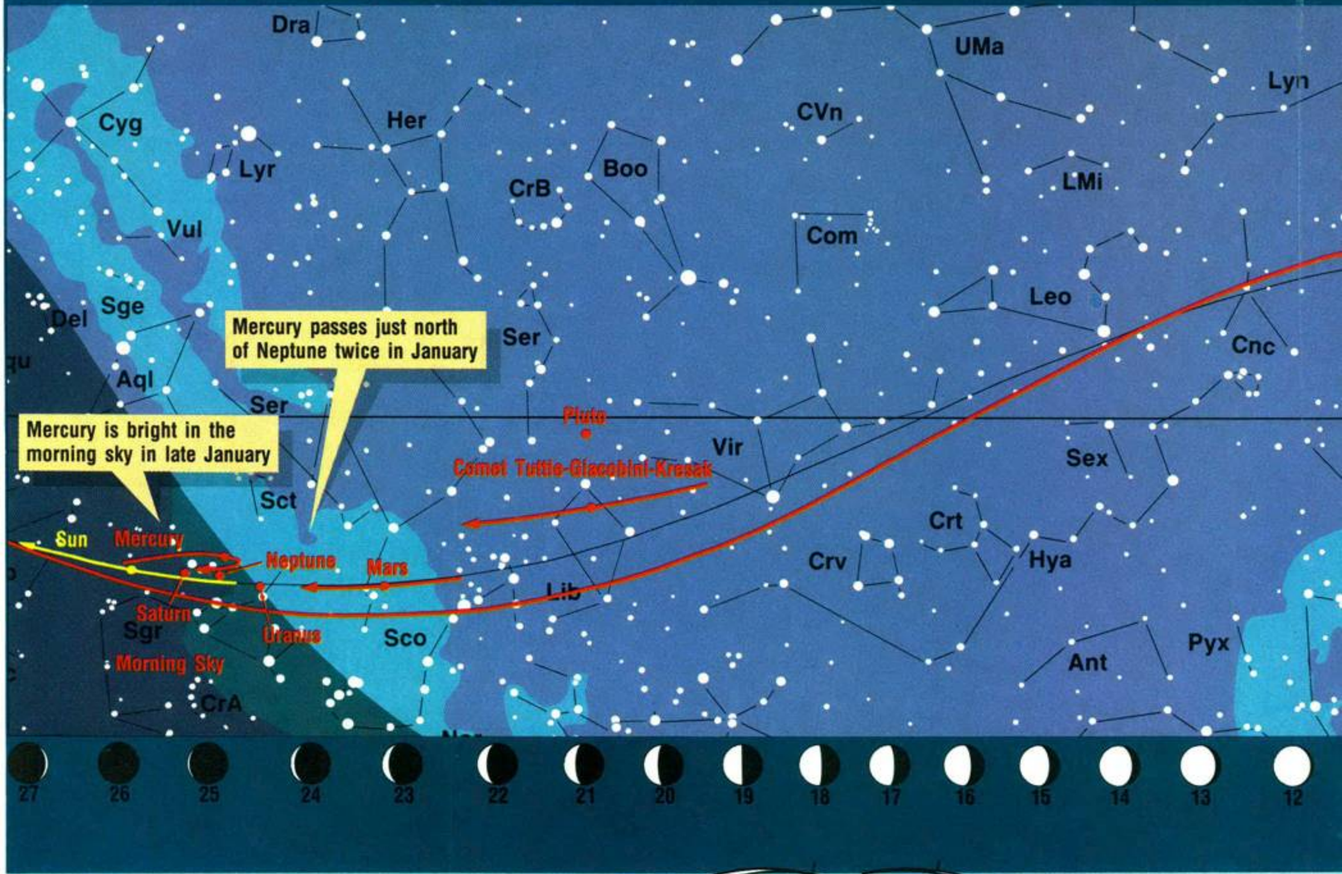
A very unusual periodic comet, Comet Tuttle-Giacobini-Kresak, passes perihelion on February 7/8 and is well-placed in the morning sky during January. The comet is making its best return since 1973, when it underwent two huge outbursts and brightened by ten magnitudes.

In January Comet Tuttle-Giacobini-Kresak moves from Virgo through Libra into Scorpius and is predicted to shine at around 12th magnitude. Use the finder chart or the table of coordinates above to locate the comet and then keep an eye on it — it may flare again. □

COORDINATES FOR COMET TUTTLE-GIACOBINI-KRESAK

Date	R.A. (2000)	Dec.
Jan. 1	14h08.1m	−9°15′
Jan. 4	14h22.3m	−10°00′
Jan. 7	14h36.7m	−10°44′
Jan. 10	14h51.3m	−11°25′
Jan. 13	15h06.0m	−12°02′
Jan. 16	15h20.8m	−12°37′
Jan. 19	15h35.6m	−13°08′
Jan. 22	15h50.3m	−13°35′
Jan. 25	16h05.0m	−13°58′
Jan. 28	16h19.6m	−14°18′
Jan. 31	16h34.0m	−14°34′

The Solar System January 1990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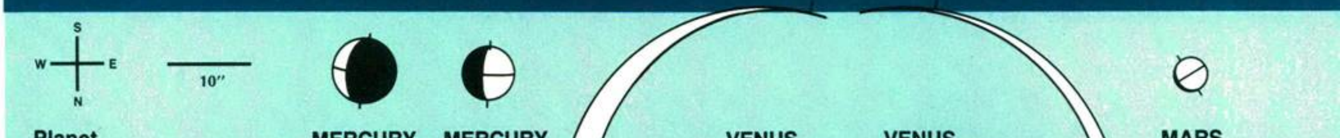
Mercury passes just north of Neptune twice in January

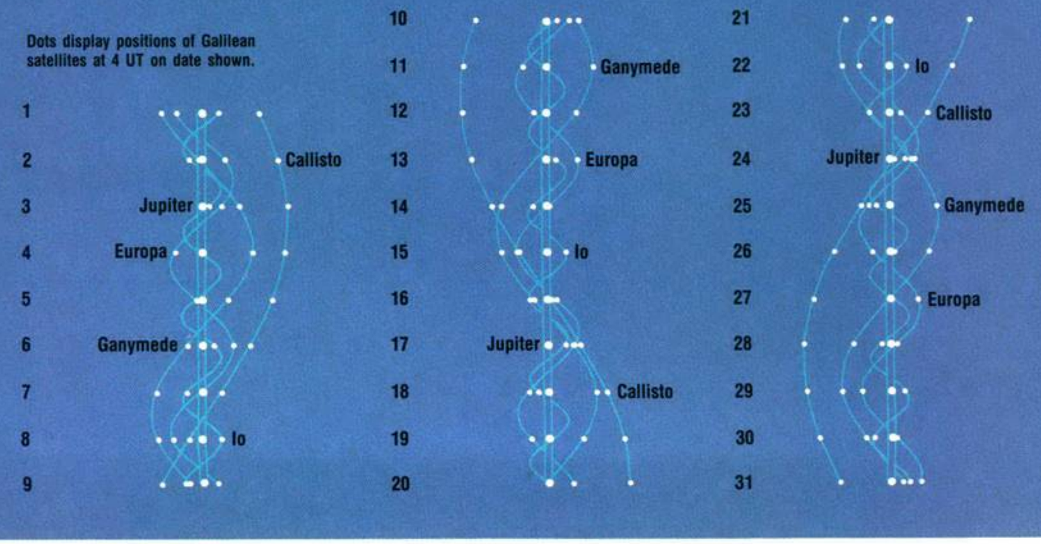
Mercury is bright in the morning sky in late January

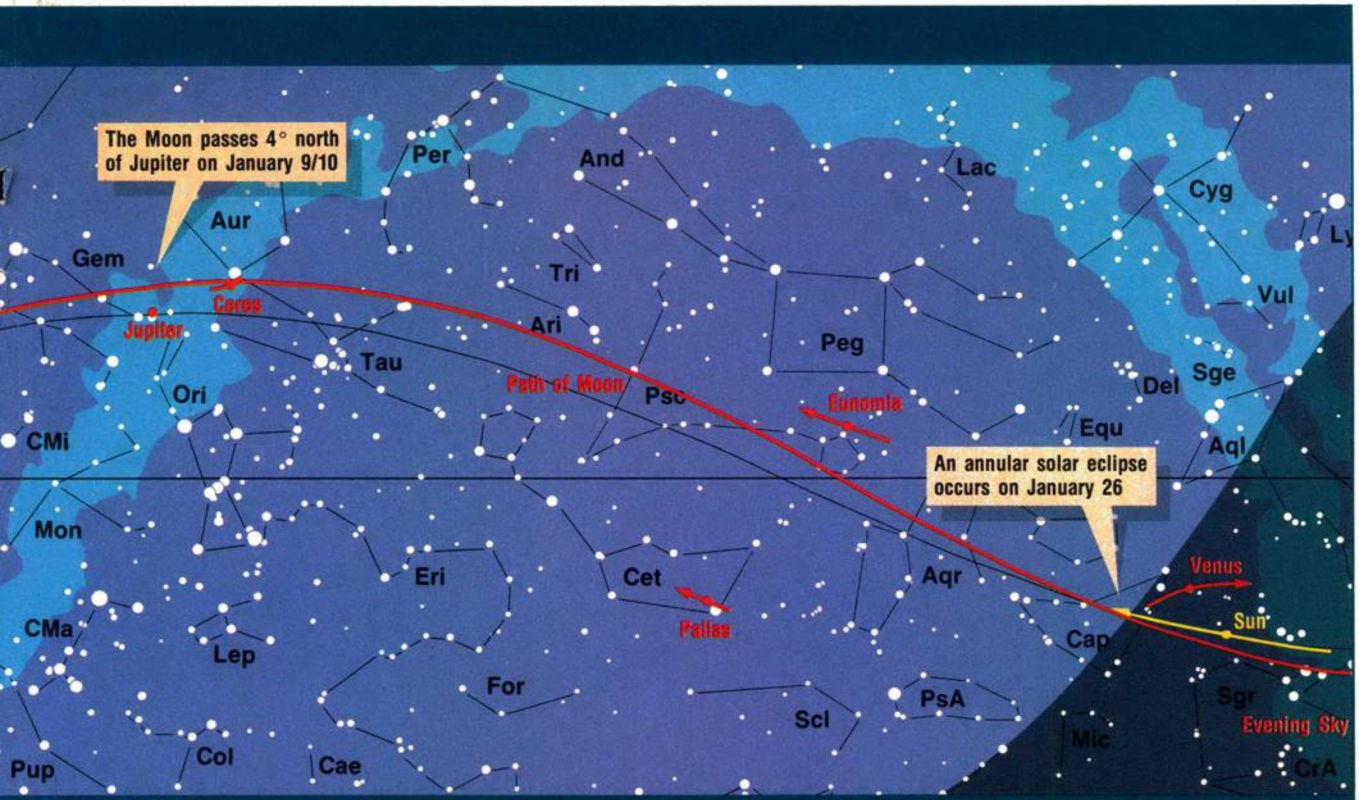


Planet	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	January 1	January 31	January 1	January 31	January 15
Magnitude	+0.7	−0.1	−4.6	−4.4	+1.5
Angular Size	8.60″	6.86″	54.2″	57.4″	4.2″
Illumination	23%	60%	10%	6%	96%
Distance (AU) from Earth	0.782	0.980	0.308	0.291	2.228
Distance (AU) from Sun	0.310	0.427	0.720	0.718	1.530
Right Ascension (2000.0)	19h51.3m	19h08.4m	20h33.4m	19h32.2m	17h15.1m
Declination (2000.0)	−20°30′	−21°25′	−16°57′	−14°16′	−23°14′

Jupiter's Moons

Dots display positions of Galilean satellites at 4 UT on date shown.

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Aql
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Aqr
Venus
Pallas
CMa
Sun
Cap
Lep
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Evening Sky
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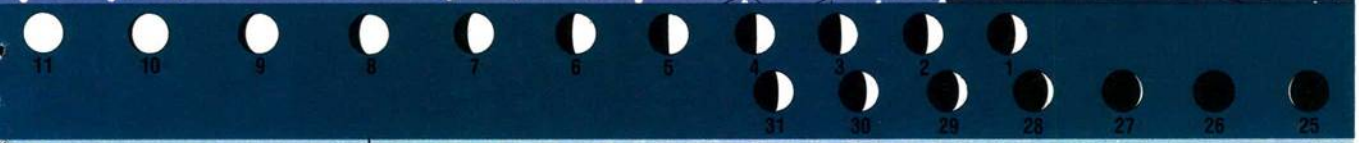
Pup
CrA

The Moon passes 4° north of Jupiter on January 9/10

An annular solar eclipse occurs on January 26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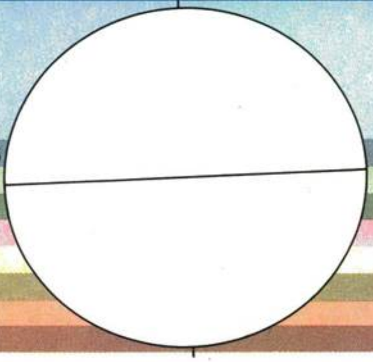
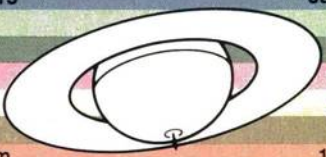
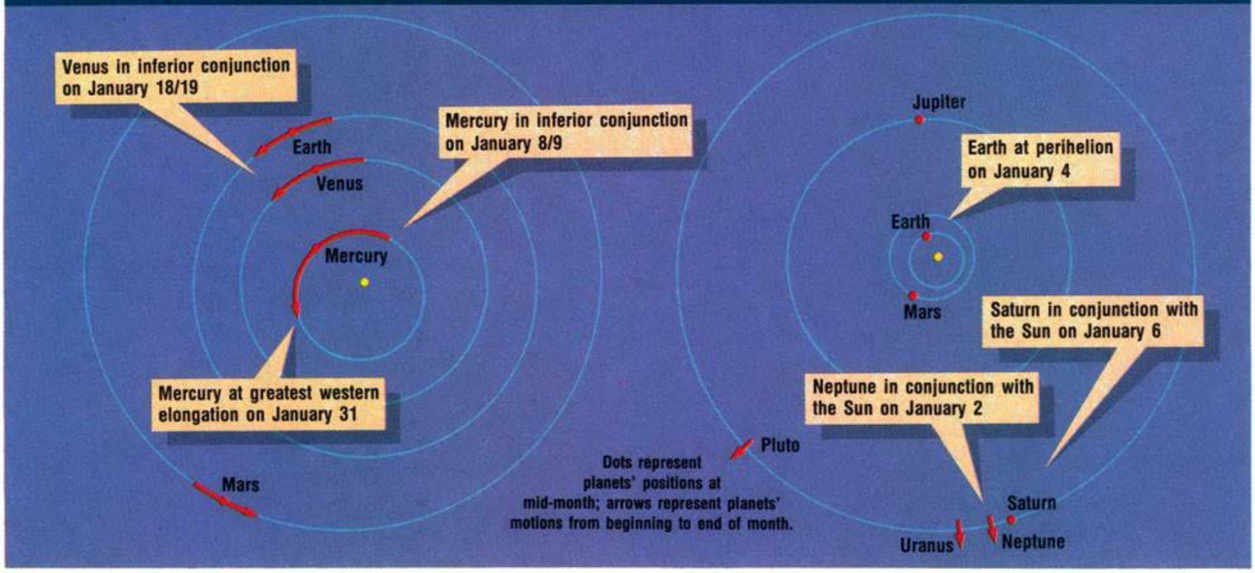




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
January 15	January 15	January 15	January 15	January 15
−2.7	+0.5	+5.8	+8.0	+13.7
46.6″	15.0″	3.4″	2.1″	0.1″
100%	100%	100%	100%	100%
4.226	11.001	20.316	31.171	30.011
5.156	10.026	19.383	30.210	29.657
16h15.5m	19h15.3m	18h29.4m	18h54.8m	15h17.5m
23°19′	−22°02′	−23°33′	−22°00′	−2°17′

The Planets in Their Orbits


Earth
Venus
Mercury
Mars
Jupiter
Earth
Mars
Pluto
Saturn
Uranus
Neptune

Venus in inferior conjunction on January 18/19

Mercury in inferior conjunction on January 8/9

Mercury at greatest western elongation on January 31

Earth at perihelion on January 4

Saturn in conjunction with the Sun on January 6

Neptune in conjunction with the Sun on January 2

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

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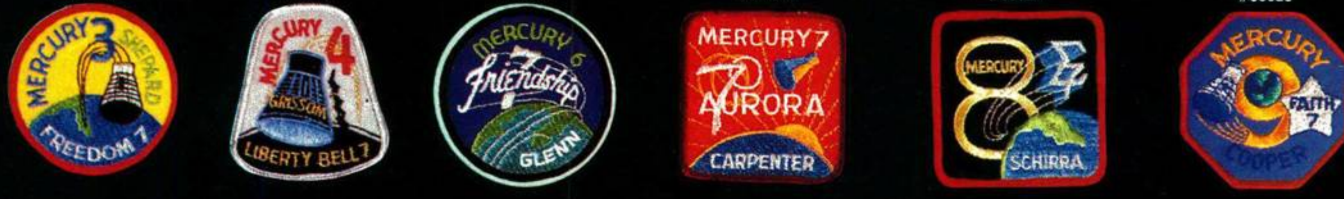
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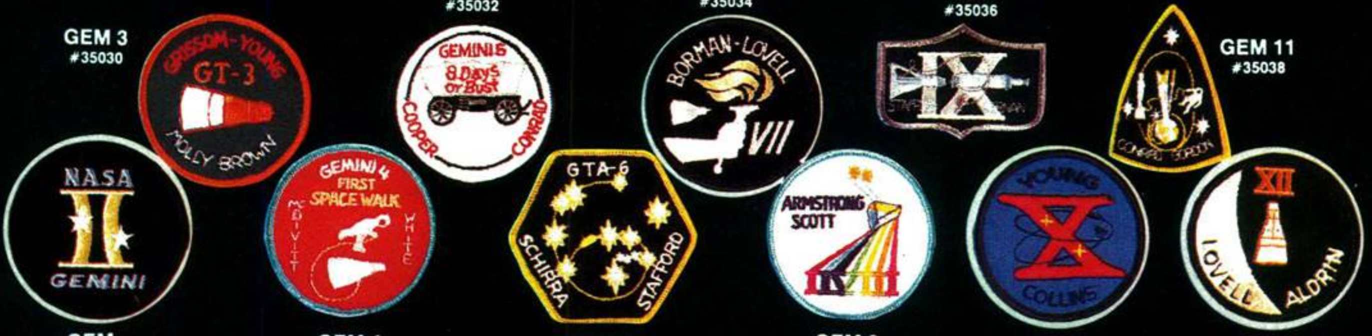
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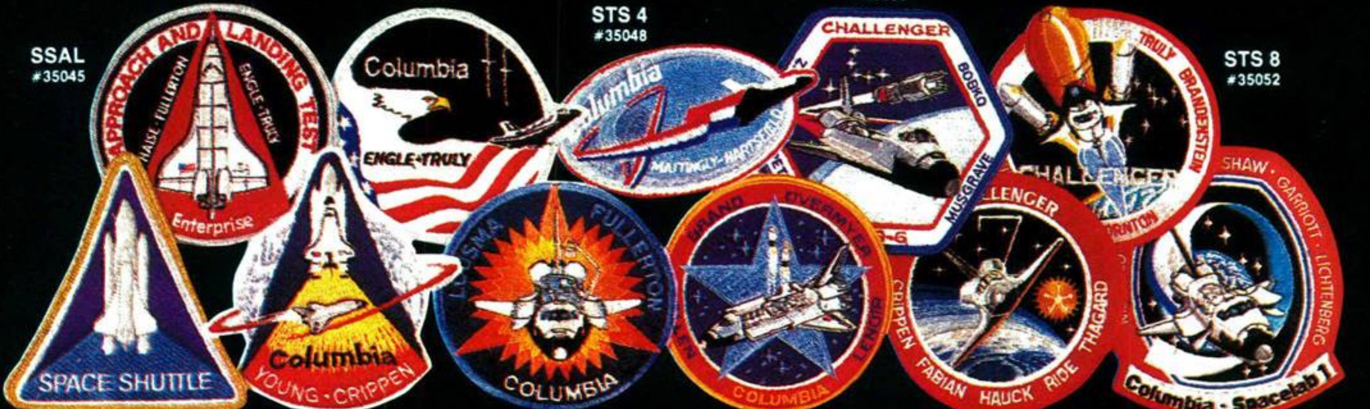
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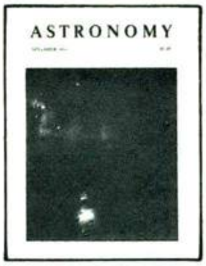

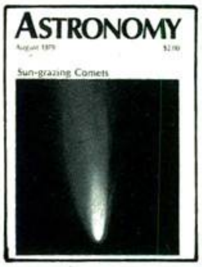

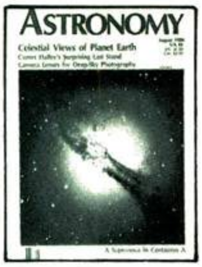

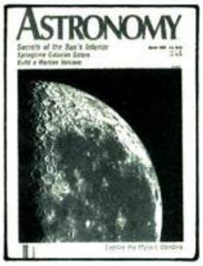

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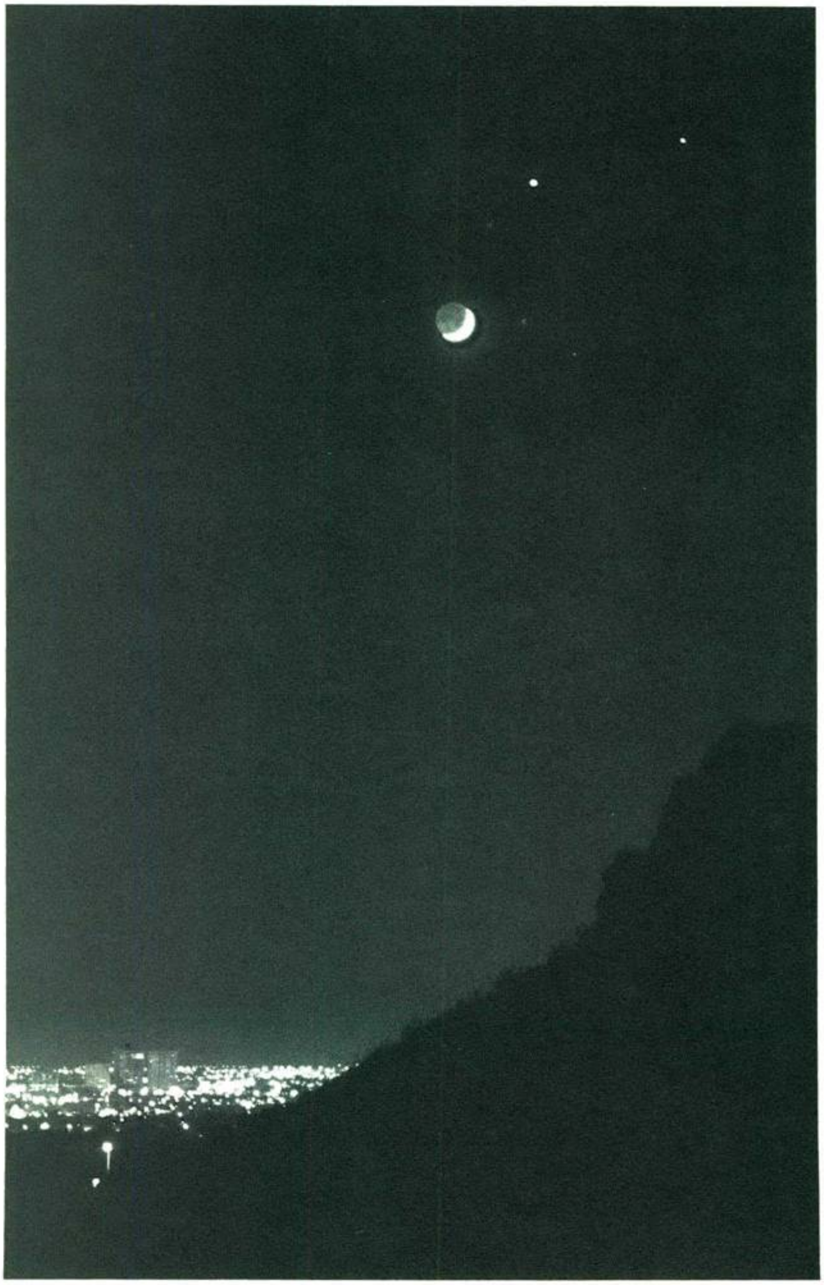
ASTRONOMY'S 1990 Sky Guide

Great celestial events are coming your way in 1990.
Here's your complete guide for planning the year's skywatching.
by Robert Burnham



THE MOON, VENUS, AND JUPITER formed a graceful arc in the evening sky over Phoenix on November 25, 1984, in this conjunction photo by Frank Zullo.

In every issue of ASTRONOMY, Sky Almanac is your guide to what's happening in the solar system. But backyard astronomers also need to know about events two months, six months — or more — down the road. To meet this need, our annual Sky Guide gives you a year-long overview of upcoming events.

Eclipses

The four eclipses of 1990, two solar and two lunar, barely touch North America. On January 26 an annular solar eclipse occurs over Antarctica, with partial phases visible from the southern half of South America and the South Island of New Zealand.

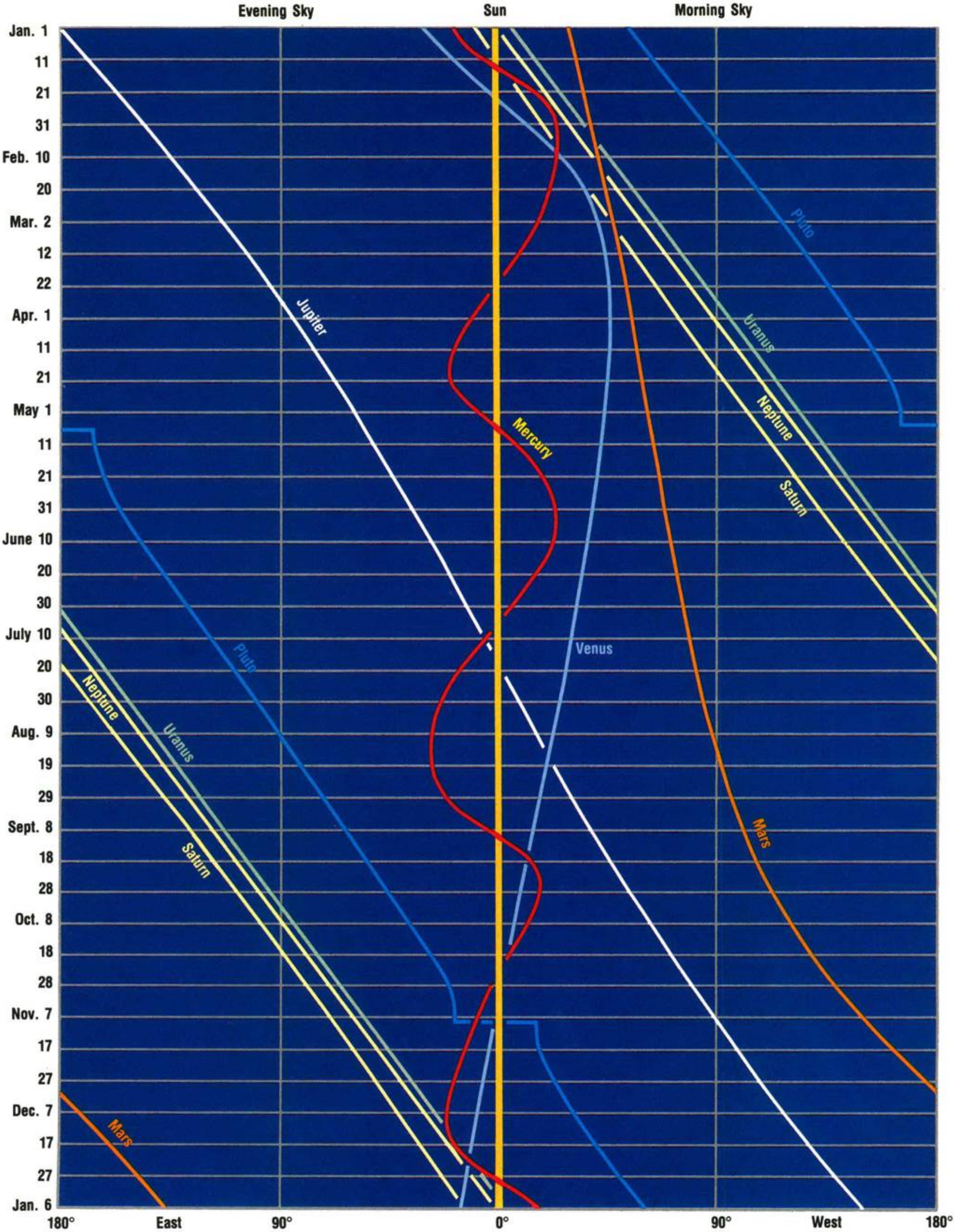
Two weeks later on February 9, a total lunar eclipse takes place; observers in Alaska, British Columbia, and Hawaii can witness the initial phases just before moonset. At the other end of the continent, Labrador, Newfoundland, and the other Maritime Provinces can see the final phases of the eclipse right after moonrise. (See the diagram on page 77.)

The year's second solar eclipse is total, and it occurs on July 22. The path of totality starts in Finland near Helsinki, where the weather prospects are best although the Sun at mid-eclipse is only 5° high. The path then travels northeast on a track that parallels the Soviet arctic coastline (see the map on page 76.) Although the eclipsed Sun stands higher (40°) here than in Finland, clouds are much more likely.

Maximum eclipse occurs near Markovo and lasts 2 minutes and 36 seconds. The path of totality then slices southeast across eastern Siberia and sweeps out to sea, crossing the Aleutian Islands before the eclipse ends halfway between Hawaii and the U.S. mainland.

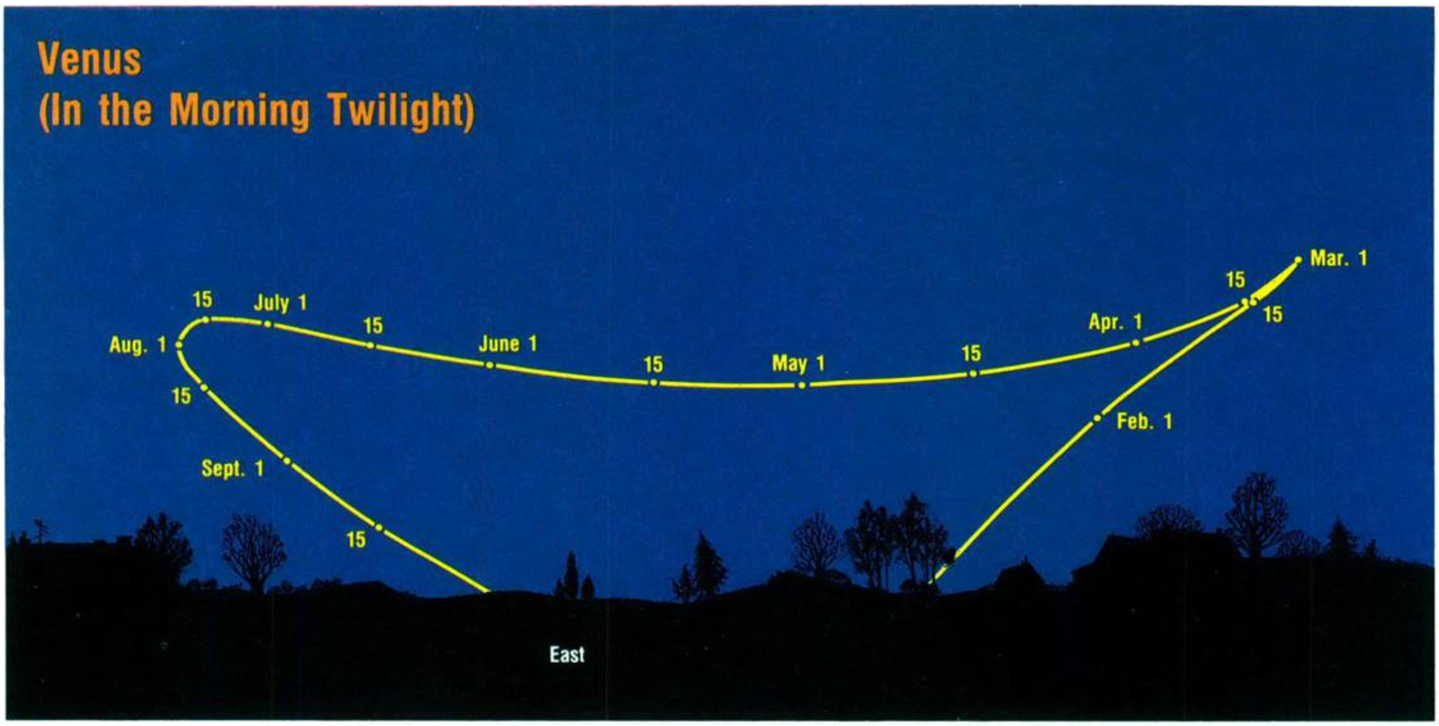
Northwestern North America — mainly Alaska, British Columbia, and the Northwest Territories — will see a

Elongations of the Planets

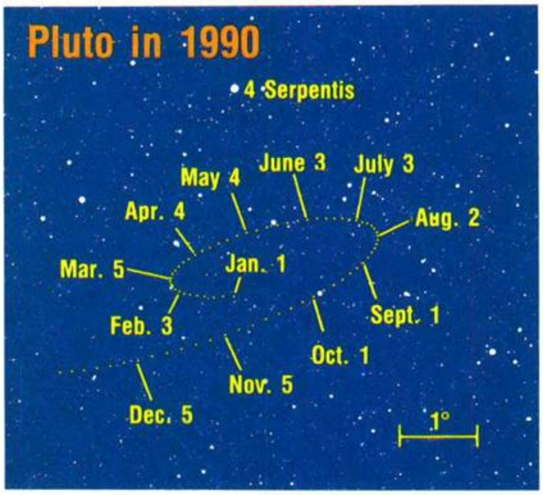


Planets that lie east of the Sun are visible in the evening sky after sunset; those to the west of the Sun are visible in the morning sky before sunrise. Opposition occurs when a planet has an elongation of 180°; the planet is then highest in the sky at midnight. (Pluto's path differs markedly from the others because it lies about 17° away from the ecliptic.)

Venus (In the Morning Twilight)



Pluto in 1990

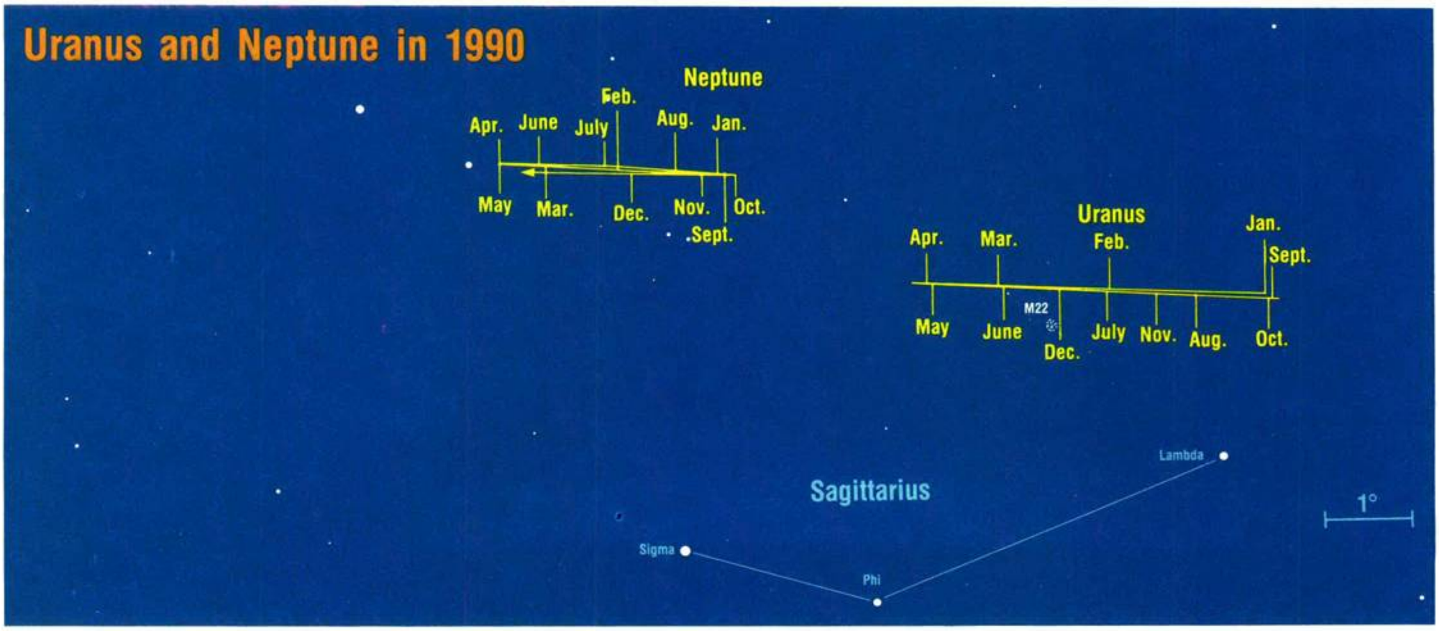


Seeing Mercury in 1990

Date of Elongation	Time of Day	Chances of Seeing It
February 1	Morning	Good
April 13	Evening	Year's Best
May 31	Morning	Poor
August 11	Evening	Year's Worst
September 24	Morning	Excellent
December 6	Evening	Fair

Mercury is usually visible at a low elevation for about two weeks before and after elongations rated "good" or better.

Uranus and Neptune in 1990



partial eclipse shortly before sunset, weather permitting. The percentage of Sun covered varies: for instance, it is 71 percent at Anchorage, 62 percent at Vancouver, and 63 percent at Seattle.

On August 6, the Full Moon will pass through the northern part of the Earth's shadow, but at maximum the Moon will be only 68 percent into the umbra. In North America the favored region once again is the West Coast, where the beginning of the umbral phase is visible before moonset. Hawaiians can see the whole eclipse, except for the end of the penumbral phase after mid-eclipse.

Mercury

The solar system's innermost planet will briefly emerge into visibility to the east or west of the Sun six times in 1990. Three such "elongations" occur in the morning sky and three in the evening.

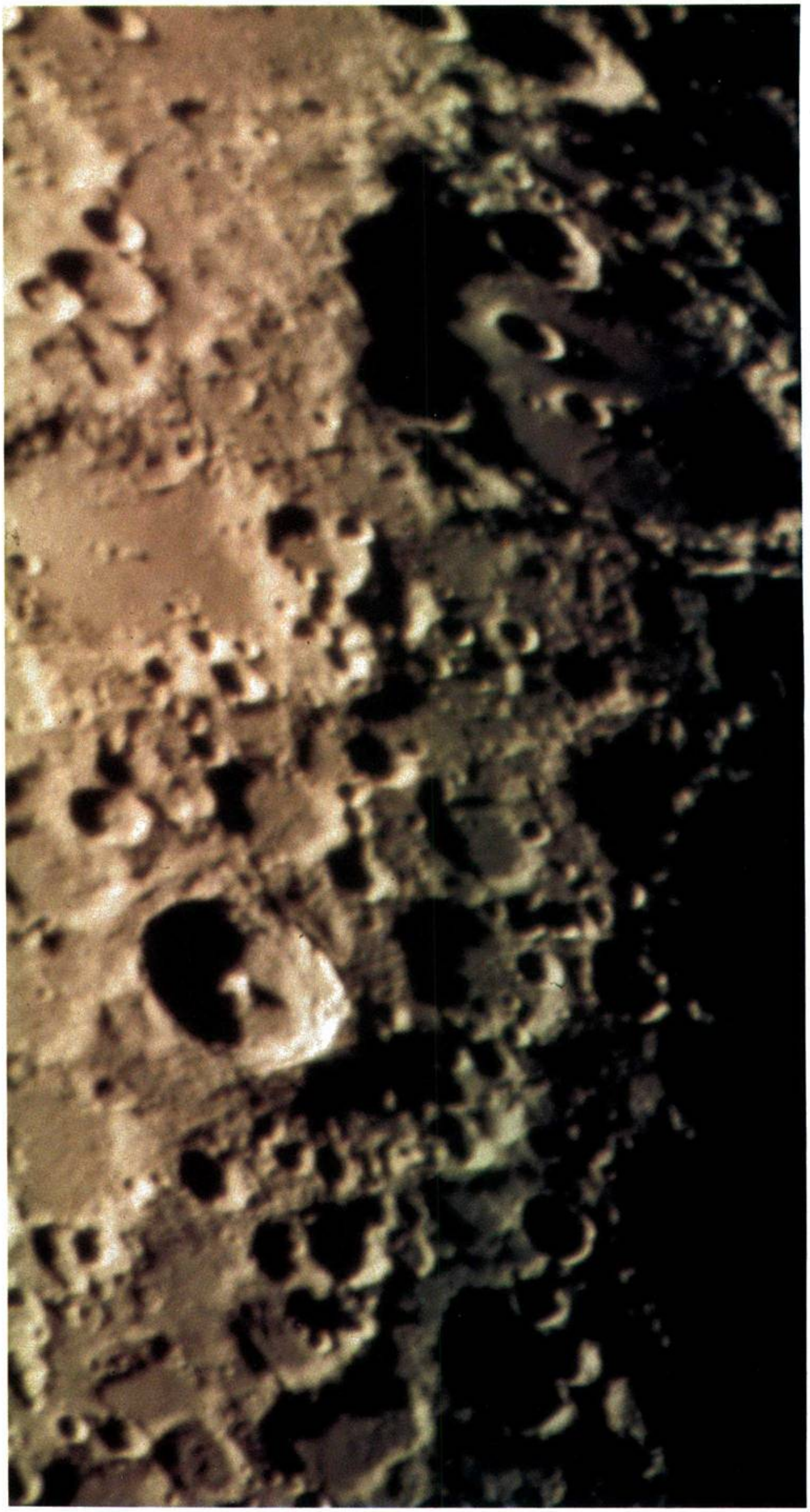
One of the best opportunities to see Mercury — and certainly the most spectacular — comes at the morning elongation on **February 1**. If you look low in the southeast as morning twilight begins to turn the sky deep blue, you will see Mercury — plus Venus, Saturn, and Mars, *and* (in binoculars or a telescope) Uranus and Neptune — all against the stellar backdrop of Sagittarius. Only Jupiter and Pluto are missing from this picture-perfect sight.

Venus is on the left, the brightest object (magnitude −4.5) in view; Mercury (−0.1 magnitude) and dimmer Saturn (0.6 magnitude) lie to its lower right. Amber Mars (1.4 magnitude) lies to the upper right of Mercury and Saturn above Sagittarius' Teapot asterism. Forty-five minutes before sunrise, Mercury is about 7° high, and a telescope with medium-high magnification will show its 60 percent-illuminated disk, 6.7" in diameter.

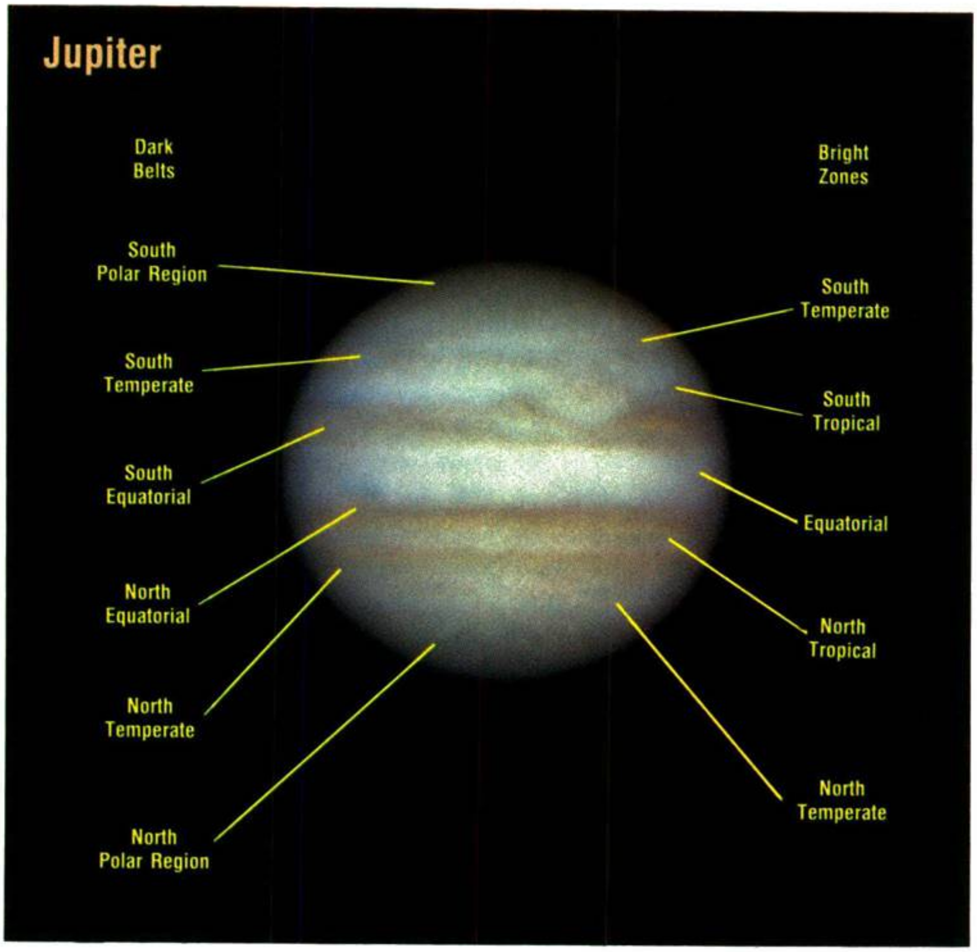
Mercury and its companions will remain together about a week. Then, on March 20, Mercury passes behind the Sun and moves into the evening sky, where on **April 13** it reaches its best elongation (10° high in the west, forty-five minutes after sunset) for the whole year.

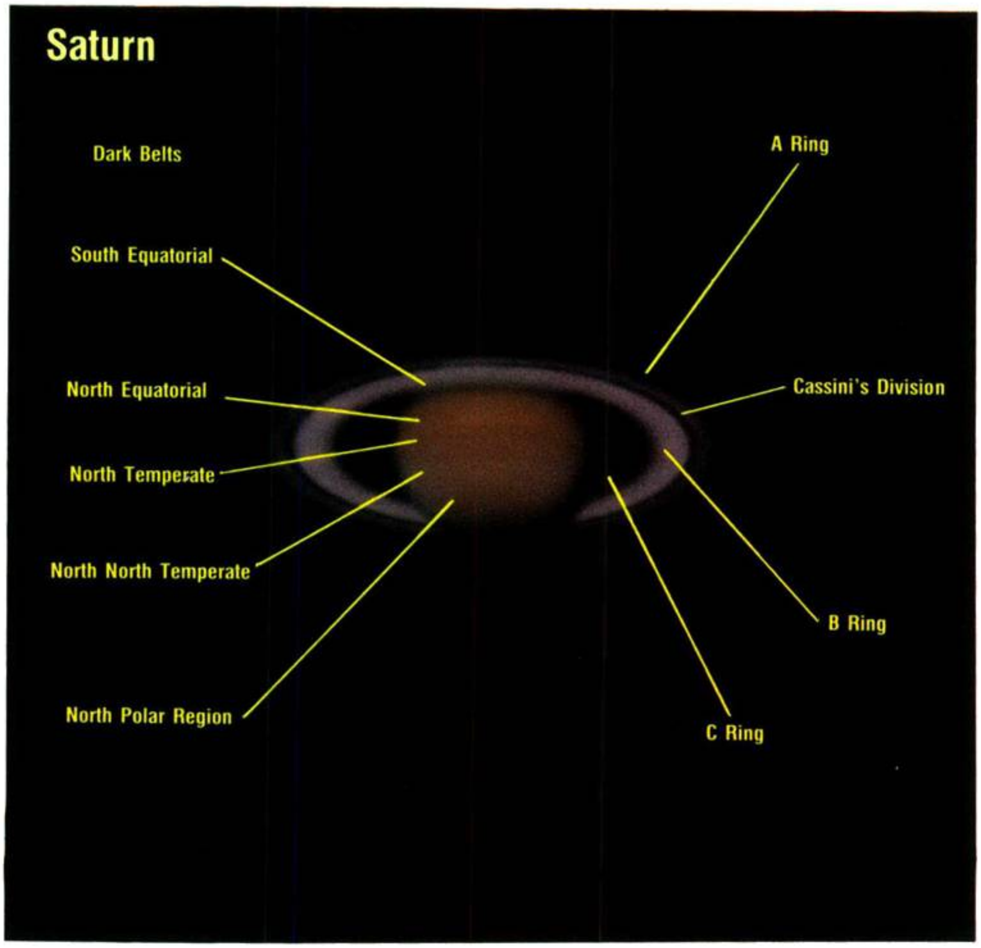
Because Mercury is now between Cetus and Aries, there are no bright stars nearby, although the Pleiades lie about 13° above the planet. In a telescope 0.0-magnitude Mercury has a diameter of 7.6" and appears 42 percent lit.

During the next two weeks, Mercury drops lower each evening toward the sunset, and on May 4 it passes between Earth and the Sun. The morning elongation that follows on **May 31** offers a poor chance to see



THE CRATERS CLAVIUS AND TYCHO dominate the Moon's south-central highlands and provide a richly detailed terrain to explore by telescope. Jean Dragesco photo.


Jupiter
Dark Belts
Bright Zones
South Polar Region
South Temperate
South Temperate
South Tropical
South Equatorial
Equatorial
North Equatorial
North Tropical
North Temperate
North Temperate
North Polar Region


Saturn
Dark Belts
A Ring
South Equatorial
North Equatorial
Cassini's Division
North Temperate
North North Temperate
B Ring
North Polar Region
C Ring

0.6-magnitude Mercury because its elevation is only 3°. Mercury's 40 percent-illuminated disk is 8.2″ across, but bad seeing near the horizon precludes good telescopic views. Venus (−4.0 magnitude) lies to the upper right and is far more conspicuous.

Mercury reaches superior conjunction with the Sun on July 2, and the planet's next elongation occurs in the evening on **August 11**. Unfortunately, it's the year's worst, with 0.4-magnitude Mercury reaching a lowly 2° elevation under the tail of Leo. The morning elongation that follows on **September 24** will be one of the year's best.

Shining at magnitude −0.4 in the eastern twilight, Mercury will be in Leo at 8° elevation, about halfway between Regulus and the horizon. In a telescope Mercury will display a half-lit disk, 7.1″ in diameter.

After superior conjunction on October 22, Mercury appears in the evening sky, reaching greatest elongation on **December 6** in Sagittarius. Mercury's 6.5″ disk is at −0.4 magnitude and appears 60 percent illuminated; its elevation is about 5°.

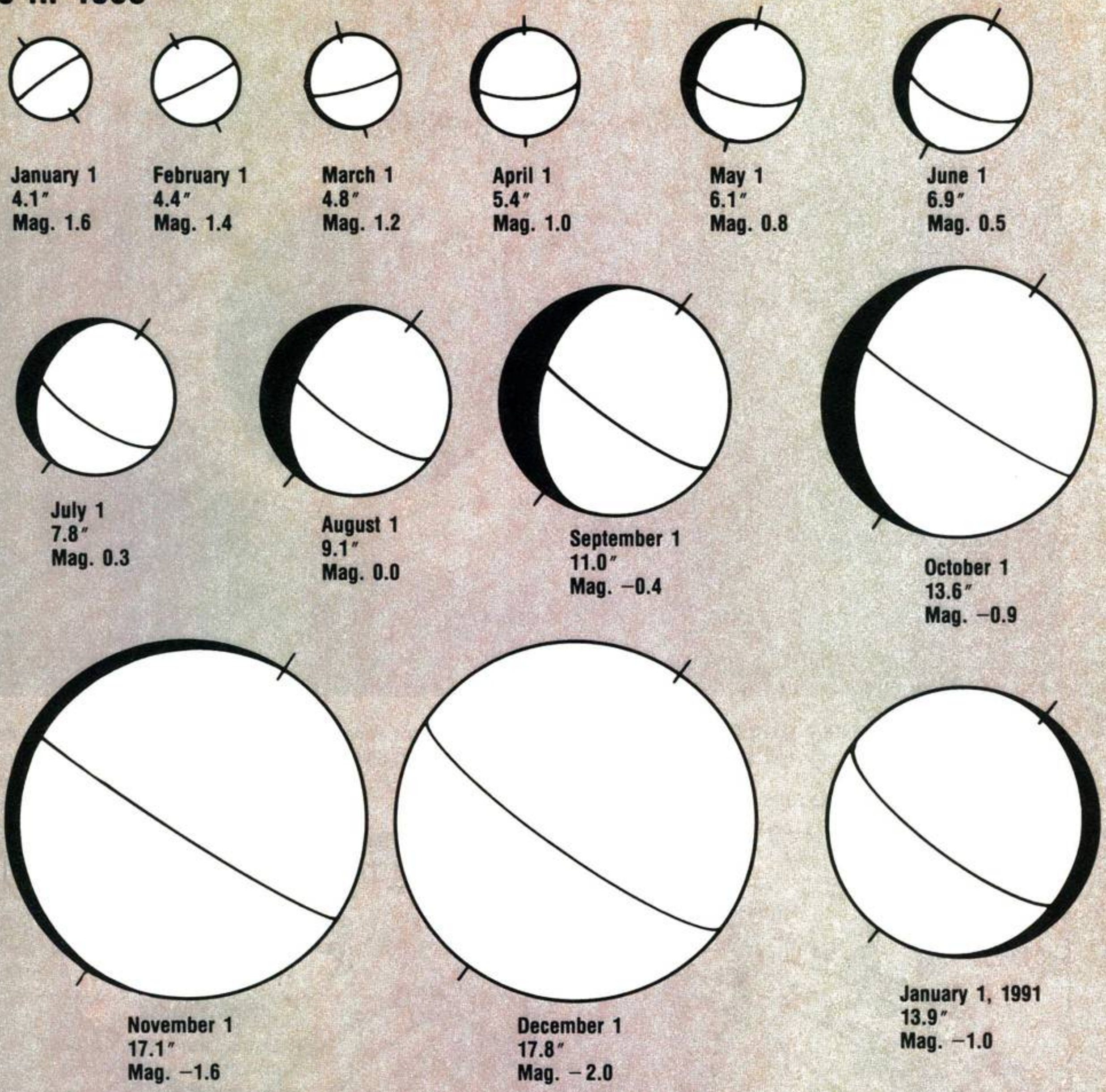
To locate Mercury, scan with binoculars or a low-power finder scope. For morning elongations it's best to start looking about an hour before local sunrise; in the evening begin looking for Mercury right after the Sun dips below the horizon. Focus the binoculars on a distant object and then slowly sweep the horizon from side to side. Mercury will look like an amber-colored star, and a telescope will reveal its disk. Once you locate it in binoculars, seeing the planet with the naked eye is usually easy.

Venus

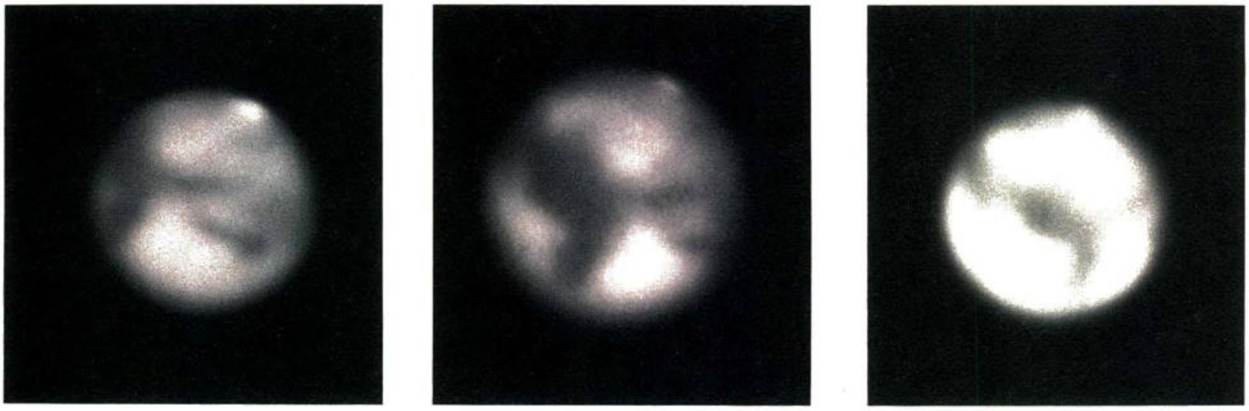
After its vivid apparition in the evening sky in late December and early January, Venus disappears from view as it passes between the Earth and Sun on January 18 and then reappears in the morning sky. Start looking for Venus each morning low in the east-southeast during the hour before sunrise beginning around January 21. By February 1, Venus is prominent in the predawn sky. Passing greatest brilliancy on February 22, Venus reaches its highest elevation for the year on March 1, although greatest elongation occurs on March 30. (The diagram on page 72 shows Venus' track above the eastern horizon forty-five minutes before sunrise.)

The best period to observe Venus' changes in apparent size and brightness with a telescope occurs between the time it pops into view in late January and greatest elongation at the

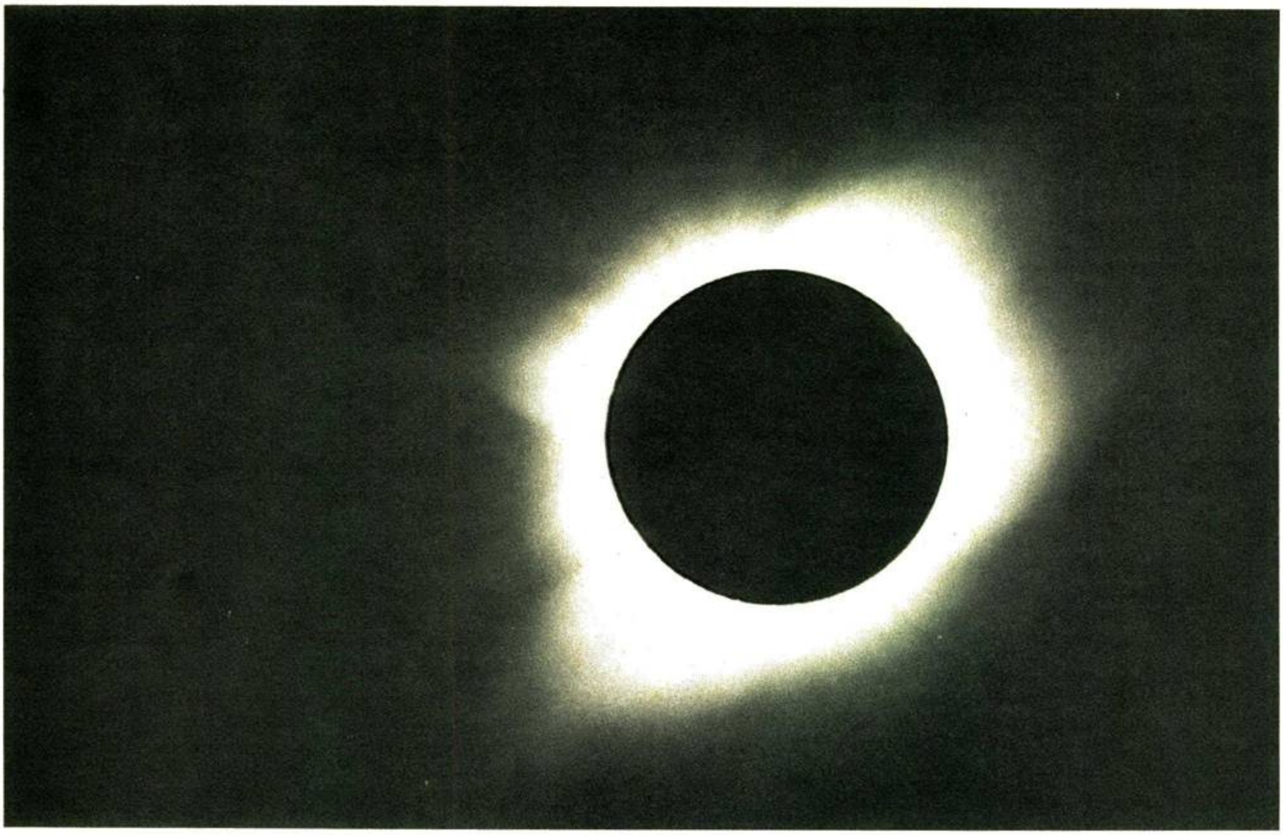
Mars in 1990


January 1
4.1″
Mag. 1.6
February 1
4.4″
Mag. 1.4
March 1
4.8″
Mag. 1.2
April 1
5.4″
Mag. 1.0
May 1
6.1″
Mag. 0.8
June 1
6.9″
Mag. 0.5
July 1
7.8″
Mag. 0.3
August 1
9.1″
Mag. 0.0
September 1
11.0″
Mag. −0.4
October 1
13.6″
Mag. −0.9
November 1
17.1″
Mag. −1.6
December 1
17.8″
Mag. −2.0
January 1, 1991
13.9″
Mag. −1.0

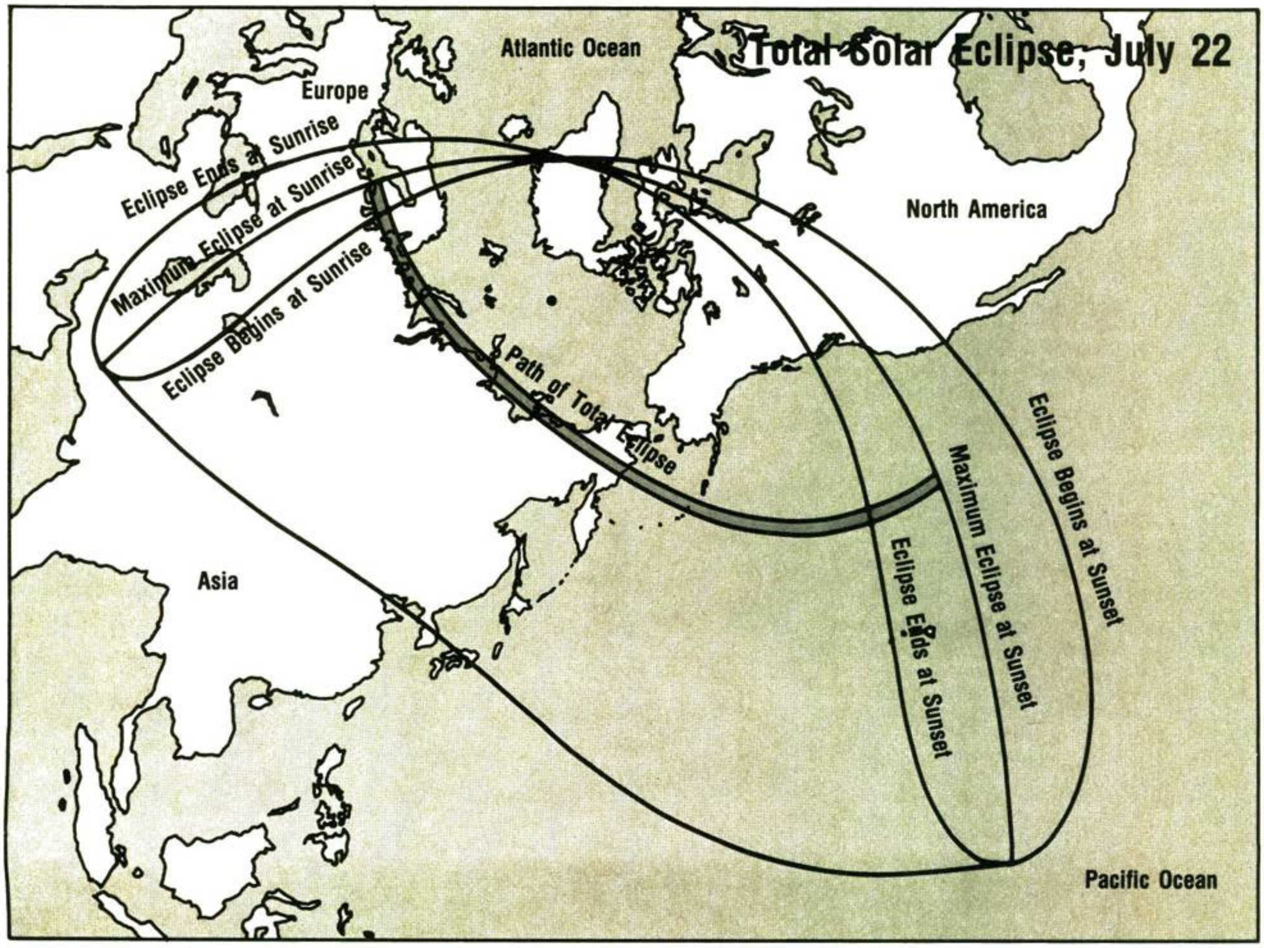
The Martian disk is shown for the first day of each month, together with its diameter and magnitude; south lies at the top to match the view in a telescope.



SYRTIS MAJOR LOOKS LIKE AFRICA in these three photos taken in 1988 on (left to right) September 26, 28, and October 1. Photos by Klaus Brasch (left and right) and Rick Schmidt (center).



LIKE AN ENORMOUS PEARLY FLOWER, the Sun's corona stands out in David Wing's photo of the total eclipse on November 24, 1984. The track of this year's total solar eclipse (below) traverses Finland and Siberia.



Total Solar Eclipse, July 22
Atlantic Ocean
Europe
North America
Eclipse Ends at Sunrise
Maximum Eclipse at Sunrise
Eclipse Begins at Sunrise
Path of Total Eclipse
Asia
Eclipse Ends at Sunset
Maximum Eclipse at Sunset
Eclipse Begins at Sunset
Pacific Ocean

end of March. All the most dramatic sights will be crammed into these eight weeks, with changes almost on a morning-to-morning basis.

On January 29, Venus is 59″ in diameter and a skinny crescent only 4 percent lit. By February 10 it is 50″ in diameter and the crescent swells to 14 percent of its diameter. By the end of February, Venus is only 36″ across but 30 percent lit.

After greatest elongation Venus' disk steadily fills out while it continues shrinking in apparent size, reaching 10″ across and 98 percent "full" by mid-September. Telescopically, however, its featureless, white disk will have increasingly little to show once the period of rapid phase and size changes is over.

To naked-eye observers Venus is visible during the spring and early summer as a bright object standing prominently above the eastern horizon every clear dawn. Look for pretty conjunctions each month as the waning crescent Moon slips past on its way to becoming a New Moon. By the end of summer, Venus is dropping toward the sunrise point as it heads for solar conjunction (November 1). Lost in the Sun's glare, Venus will be out of view from late September until it emerges into the evening sky after sunset in early January 1991 to begin another apparition.

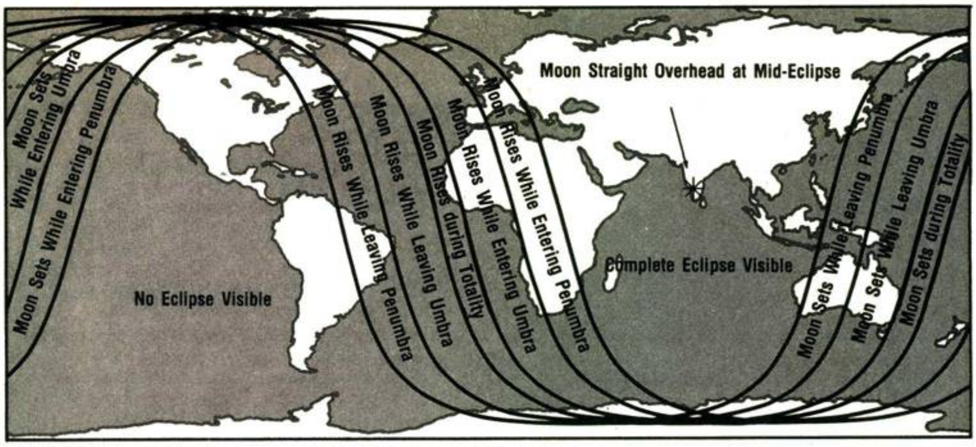
Mars

When 1990 opens, Mars lies in the southeastern sky among the stars of Sagittarius as dawn begins to break. From there Mars rises a little earlier each morning as it glides steadily eastward along the ecliptic, through the dim star figures of Capricornus, Aquarius, Pisces, and Aries into Taurus, which it reaches by late summer. Opposition occurs on November 27, with the planet lying northeast of the Hyades cluster.

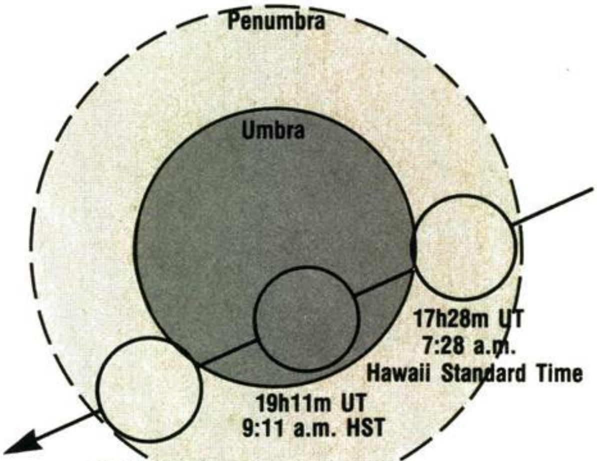
During this time Mars is slowly growing in apparent size and brightness as the distance between Earth and Mars dwindles. (See the diagram on page 75 showing the Martian disk on the first day of each month.)

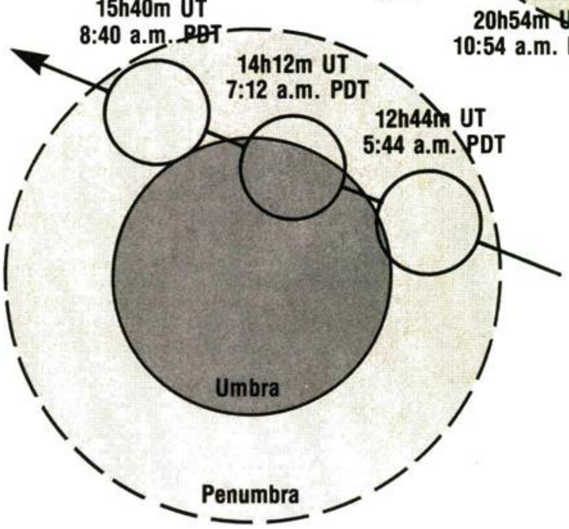
The last Mars "observing season" showed telescope owners that the Red Planet offers lots of exciting viewing — and this season promises the same. Although at this opposition Mars has an apparent size that's only 77 percent as large as in 1988 (18.1″ this year versus 23.7″ then), the planet's location in Taurus places it higher in the sky and provides much better seeing from the middle northern latitudes than in 1988.

Mars is occulted by a waning crescent Moon on March 22, an event vis-

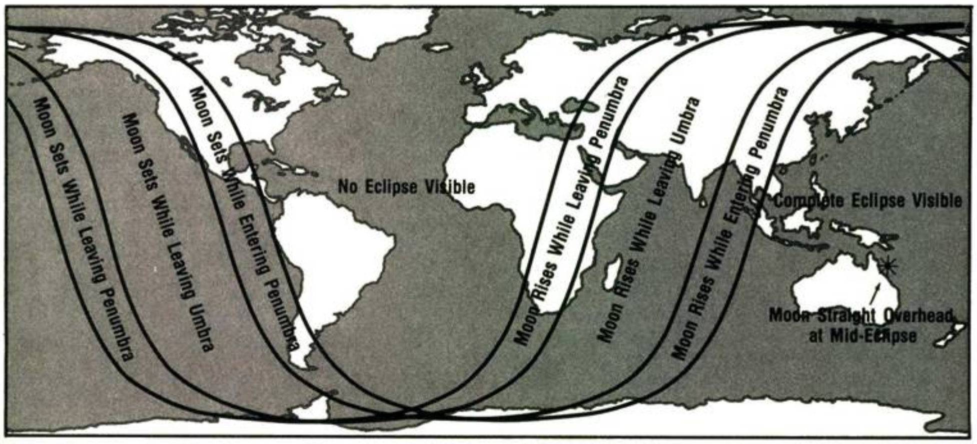

Moon Sets While Entering Umbra
Moon Sets While Entering Penumbra
No Eclipse Visible
Moon Rises While Leaving Penumbra
Moon Rises While Leaving Umbra
Moon Rises during Totality
Moon Rises While Entering Umbra
Moon Rises While Entering Penumbra
Moon Straight Overhead at Mid-Eclipse
Complete Eclipse Visible
Moon Sets While Leaving Penumbra
Moon Sets While Leaving Umbra
Moon Sets during Totality

Total Lunar Eclipse, February 9


Penumbra
Umbra
17h28m UT
7:28 a.m.
Hawaii Standard Time
19h11m UT
9:11 a.m. HST
20h54m UT
10:54 a.m. HST


15h40m UT
8:40 a.m. PDT
14h12m UT
7:12 a.m. PDT
12h44m UT
5:44 a.m. PDT
Umbra
Penumbra

Partial Lunar Eclipse, August 6


Moon Sets While Leaving Penumbra
Moon Sets While Leaving Umbra
Moon Sets While Entering Penumbra
No Eclipse Visible
Moon Rises While Leaving Penumbra
Moon Rises While Leaving Umbra
Moon Rises While Entering Penumbra
Complete Eclipse Visible
Moon Straight Overhead at Mid-Eclipse

ible primarily from the United States (see the map on page 79).

Jupiter

When the cold, blue light of evening darkens in January, brilliant Jupiter stands above the eastern horizon amidst the stars marking the feet of Gemini. At −2.7 magnitude, the planet is unmistakable even in a region of sky with many bright stars. A telescope will show Jupiter's banded disk 46" across the equator.

During the planet's stay in the evening sky, which will last until the Sun finally catches up to it in late June, Jupiter will remain an eye-catching sight in Gemini. The constellation's high arc across the sky each night places the planet in a position where telescopic viewers are likely to have good seeing conditions.

After the dramatic fading of the South Equatorial Belt last year, Jupiter-watchers are eagerly observing the planet, hoping to catch and follow its reappearance. The South Equatorial Belt all but vanished before (in 1928 and 1958). Both times, when it returned to prominence, the "reappearance" was sudden and equally as dramatic as the fading. Telescope owners will therefore find it well worth the time to monitor Jupiter closely this year. (The diagram on page 75 gives a guide to the names of the Jovian belts and zones.)

When Jupiter disappears into the sunset glow in early summer (solar conjunction is on July 15), it will be out of sight for about a month, reappearing low in the northeast before sunrise toward the end of July. When it becomes visible again, Jupiter will be a bright beacon in Cancer, shining at −1.8 magnitude and sporting a disk 32" across; it remains in Cancer the rest of the year.

On August 18 the waning crescent Moon occults Jupiter for most of North America. (The Gulf Coast, southern Georgia, and all of Florida see a close conjunction, with Jupiter lying just south of the Moon.) Viewers stationed along the southern limit will see an exciting grazing occultation, as mountains on the limb of the Moon partially cover the planet's disk. We will publish more detailed predictions as the event draws nearer.

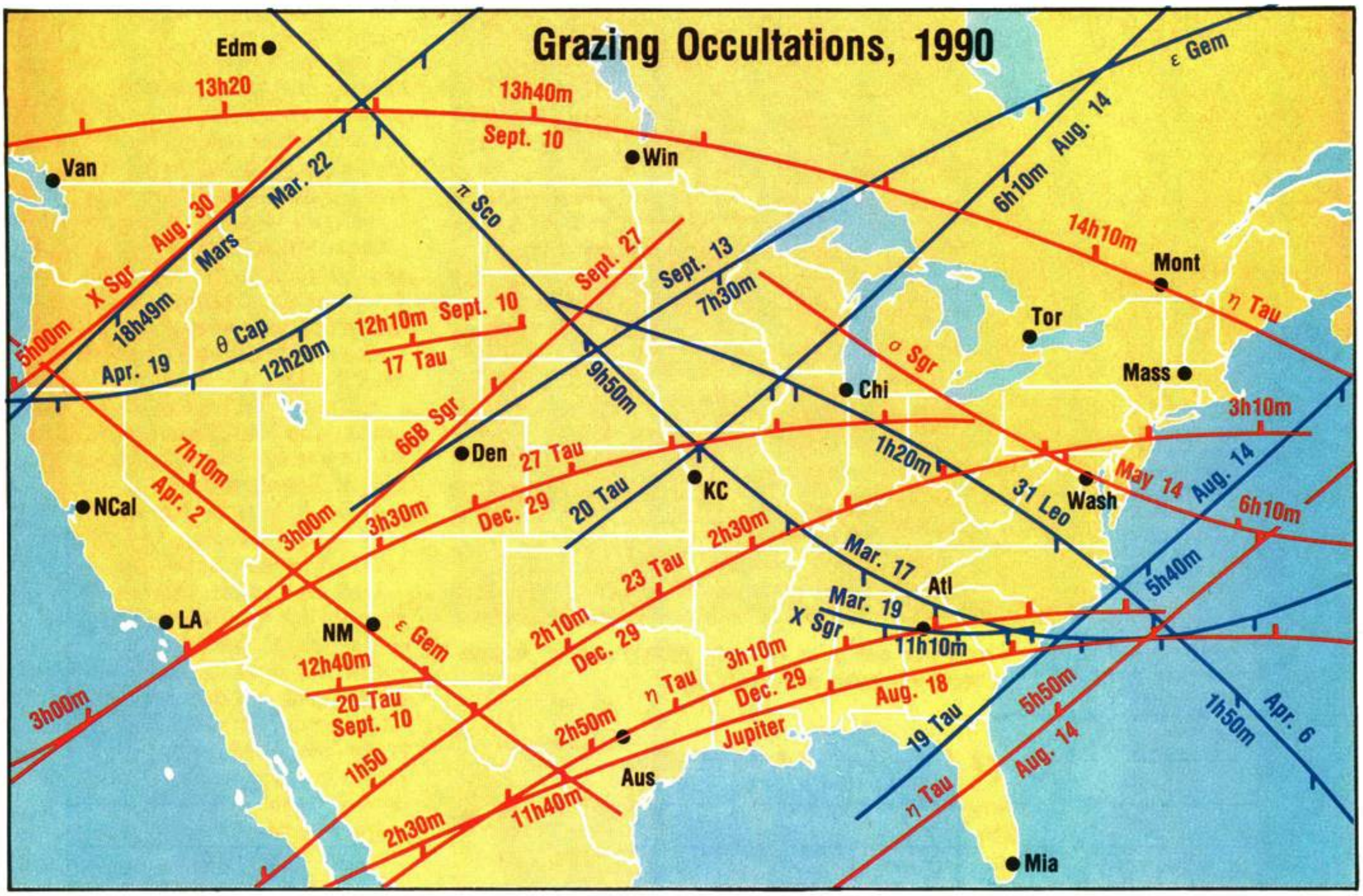
Between September 23 and 26, Jupiter passes about 2° south of the Beehive Cluster (M44), a large and loose open star cluster. The passage will provide a fine "photo-op" for any astrophotographer, novice or pro.

Saturn and the Outer Gas Giants

By 1990 Saturn has finally overtaken Uranus and Neptune and lies to

THE MOON CREPT UP ON JUPITER and then covered it in this photo by Martin Germano taken on April 2, 1983. An occultation of Jupiter occurs this year on August 18.

Grazing Occultations, 1990


Edm
13h20
13h40m
Sept. 10
Win
Van
Mar. 22
π Sco
Aug. 30
X Sgr
Mars
5h00m
18h49m
θ Cap
Apr. 19
12h20m
12h10m Sept. 10
17 Tau
Sept. 27
Sept. 13
7h30m
9h50m
66B Sgr
Den
27 Tau
20 Tau
Dec. 29
3h30m
3h00m
KC
7h10m
Apr. 2
NCal
LA
NM
ε Gem
12h40m
20 Tau
Sept. 10
1h50
2h30m
11h40m
2h50m
Aus
η Tau
2h10m
Dec. 29
23 Tau
2h30m
3h10m
Dec. 29
Jupiter
X Sgr
Mar. 19
Mar. 17
Atl
11h10m
Aug. 18
19 Tau
η Tau
Aug. 14
5h50m
5h40m
1h50m
Apr. 6
Mia
Chi
σ Sgr
1h20m
31 Leo
Wash
May 14
Aug. 14
6h10m
3h10m
Mass
Tor
Mont
η Tau
14h10m
6h10m
Aug. 14
ε Gem
3h00m

THE MAPS SHOWS where some of 1990's occultations can be seen. If you view from north of a red line or south of a blue line, the Moon will occult the star or planet named. Tick marks on the tracks show universal time (UT) at 10-minute intervals. Time always increases eastward.

The universal times and dates of disappearances and reappearances (in bold) are in the table. To convert UT into local standard time, subtract 5 hours for EST, 6 for CST, 7 for MST, 8 for PST. (During daylight-savings time, subtract 1 hour less in each zone.)

UT Date	Object	Mag.	Van	NCal	LA	Edm	NM	Den	Aus	Win	KC	Chi	Atl	Mia	Tor	Wash	Mont	Mass	Hal
Mar. 17	π Sco	3.0		8:39	8:39		8:52	9:11	9:15		9:48		10:17	10:11					
			9:52	**9:53**	**9:57**	**9:46**	**10:09**	**10:07**	**10:31**		**10:11**		**10:40**	**11:23**					
Mar. 19	X Sgr	4.4		**10:31**	**10:33**		**10:41**	**10:36**	**10:58**										
Mar. 22	Mars	1.1			18:16		18:24	18:30	18:35	18:37		18:38	18:46						
					19:27		**19:37**	**19:37**	**19:41**										
Apr. 2	ε Gem	3.2	6:33			6:20		6:48	7:05	6:25	6:43	6:35			6:28				
Apr. 6	31 Leo	4.6											0:53	0:59					
Apr. 19	θ Cap	4.2		**12:11**	**12:18**														
May 14	σ Sgr	2.1													5:46		5:50	5:52	6:03
															6:20		**6:37**	**6:32**	**6:53**
Aug. 14	19 Tau	4.4												**5:45**					
	20 Tau	4.0									**6:03**	**6:09**	**6:09**	**6:04**	**6:17**	**6:16**	**6:23**	**6:22**	**6:32**
	η Tau	3.0				6:25				6:14	6:00	6:02	5:57		6:06	6:03	6:10	6:09	6:20
						7:14				**7:07**	**6:48**	**6:52**	**6:33**		**6:54**	**6:42**	**6:57**	**6:49**	**6:52**
Aug. 18	Jupiter	−1.8	11:32			11:37	11:17	11:19	11:31	11:30	11:23	11:28	11:41		11:36	11:40	11:42	11:43	11:54
			12:20	**12:12**	**12:08**	**12:25**	**12:07**	**12:17**	**11:54**	**12:32**	**12:20**	**12:31**	**12:12**		**12:43**	**12:38**	**12:53**	**12:51**	**13:08**
Aug. 30	X Sgr	4.4	4:38																
Sept. 10	17 Tau	3.8	**12:20**																
	20 Tau	4.0	**13:02**	**12:54**	**12:50**														
	η Tau	3.0				13:06													14:03
						13:39													**14:32**
Sept. 13	ε Gem	3.2						**7:30**	**7:39**		**7:42**	**7:46**	**7:46**	**7:40**	**7:54**	**7:54**	**8:00**	**8:03**	**8:11**
Sept. 27	66B Sgr	4.7			2:31	2:17				2:55									
Dec. 29	23 Tau	4.2	1:40	1:22	1:21	1:53	1:35	1:43		2:02	2:06	2:19			2:35		2:44	2:54	3:04
	η Tau	3.0	2:17	1:55	1:54	2:31	2:07	2:18	2:50	2:39	2:38	2:51	3:23		3:06	3:18	3:15	3:20	3:32
			3:12	**3:03**	**3:01**	**3:28**	**3:11**	**3:29**	**2:58**	**3:51**	**3:43**	**4:02**	**3:34**		**4:16**	**4:13**	**4:25**	**4:26**	**4:39**
	27 Tau	3.8	2:52	2:43	2:55	3:08		3:23		3:28		4:02			4:10		4:13	4:24	4:26

Van, Vancouver; NCal, northern California; LA, Los Angeles; Edm, Edmonton; NM, New Mexico-Arizona; Den, Denver; Aus, Austin; Win, Winnipeg; KC, Kansas City; Chi, Chicago; Atl, Atlanta; Mia, Miami; Tor, Toronto; Wash, Washington; Mont, Montreal; Mass, Massachusetts; Hal, Halifax (not shown on map).

AURORAL CURTAINS over Alaska glow pale green in Forrest Baldwin's photo. As solar activity increases this year, check for aurorae every clear night.

Look North for the Northern Lights

With the current solar cycle approaching its peak of activity this year, auroras — the northern lights — are becoming more common in the mid-northern latitudes. If you want to see these ghostly curtains of light for yourself, make it a point to check for an aurora on every clear night.

How? Just go outside and look in the northern half of the sky. Take a few moments to let your eyes adjust to the dark. You should expect clouds to produce false alarms often, but a real aurora typically has pale green curtains or streaks that slowly change shape over several seconds. Other times the aurora will resemble patches or clouds that fade away and then grow brighter from minute to minute.

Capturing an aurora on film is easy if you have a camera that lets you take time exposures (see your manual). Load the camera with fast film, print or transparency; an ISO rating of at least 400 helps, although slower films also work. Then put the camera on a tripod, focus the lens to infinity, open the f/stop as far as it goes (use the lowest number on the aperture ring), and set the shutter for a time exposure.

Aim the camera at the aurora and make exposures lasting 5, 10, and 30 seconds, and perhaps also 1 and 2 minutes if the aurora is dim and your sky is dark. Bracketing your exposures this way greatly increases the chances of getting at least one good photo.

1990's Major Meteor Showers

Name	Date	Hourly Rate	Prospects
Quadrantids	January 3	40-60	Good
Lyrids	April 22	10-15	Excellent
Eta Aquarids	May 5	10-40	Fair
S. Delta Aqr.	July 29	10-35	Good
Perseids	August 12	40-100	Fair
Orionids	October 22	25	Excellent
S. Taurids	November 4	10	Poor
Leonids	November 17	5-20	Excellent
Geminids	December 14	50-80	Excellent

The date given is for maximum activity, but all showers listed (except for the very brief Quadrantids) can be seen at diminished levels a day or two before and after the date given.

the east of them. All three objects, however, remain in Sagittarius, though Saturn is about halfway toward Capricornus, which neighbors the Archer on the east. (See the Uranus/Neptune finder chart on page 72.)

Mercury briefly joins Saturn, Uranus, and Neptune in late January and early February, and Mars and Venus are also passing through. Mars overtakes Uranus around February 10, Neptune a week later, and Saturn around March 1.

In January this region of sky rises just as dawn is brightening. Each day, the planets rise a little earlier. By the time of their oppositions in summer, they are rising as the Sun sets. Opposition dates are: Uranus, June 29; Neptune, July 5; and Saturn, July 14.

Apart from Jupiter, Saturn is the only gas giant that reveals details in a backyard telescope. (See the guide to belts, zones, and rings on page 74.) With good seeing and medium-high magnification, Saturn displays dark belts, bright zones, and occasional small clouds crossing its disk. The details, however, are more subtle than on Jupiter and take a little practice to see clearly.

Even at its best, Uranus is never more than a blue-green dot at 6th magnitude measuring 3.8″ across. Likewise, Neptune is blue-gray, 8th magnitude, and 2.3″ in diameter. (Studying this faint dot of light in a telescope, who would have thought, pre-*Voyager*, that Neptune's little disk would hold so many fascinating details?)

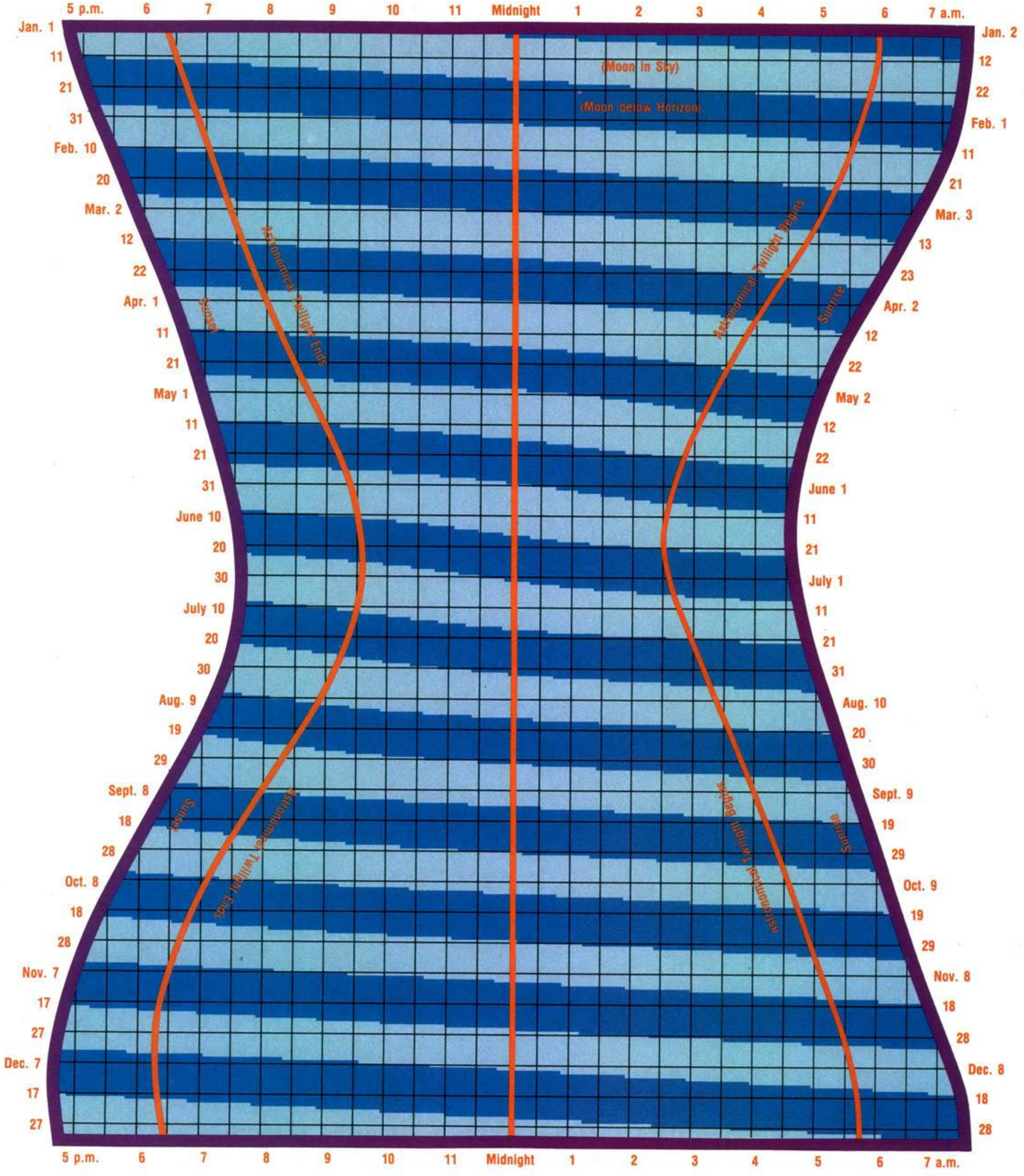
Uranus has a triple conjunction this year with the globular cluster M22. The planet passes about 1° north of the cluster around February 19 (eastbound), June 10 (westbound), and December 7 (eastbound again). The June conjunction offers the best viewing because it occurs near opposition; thus the two objects are as high and visible as they get.

Pluto

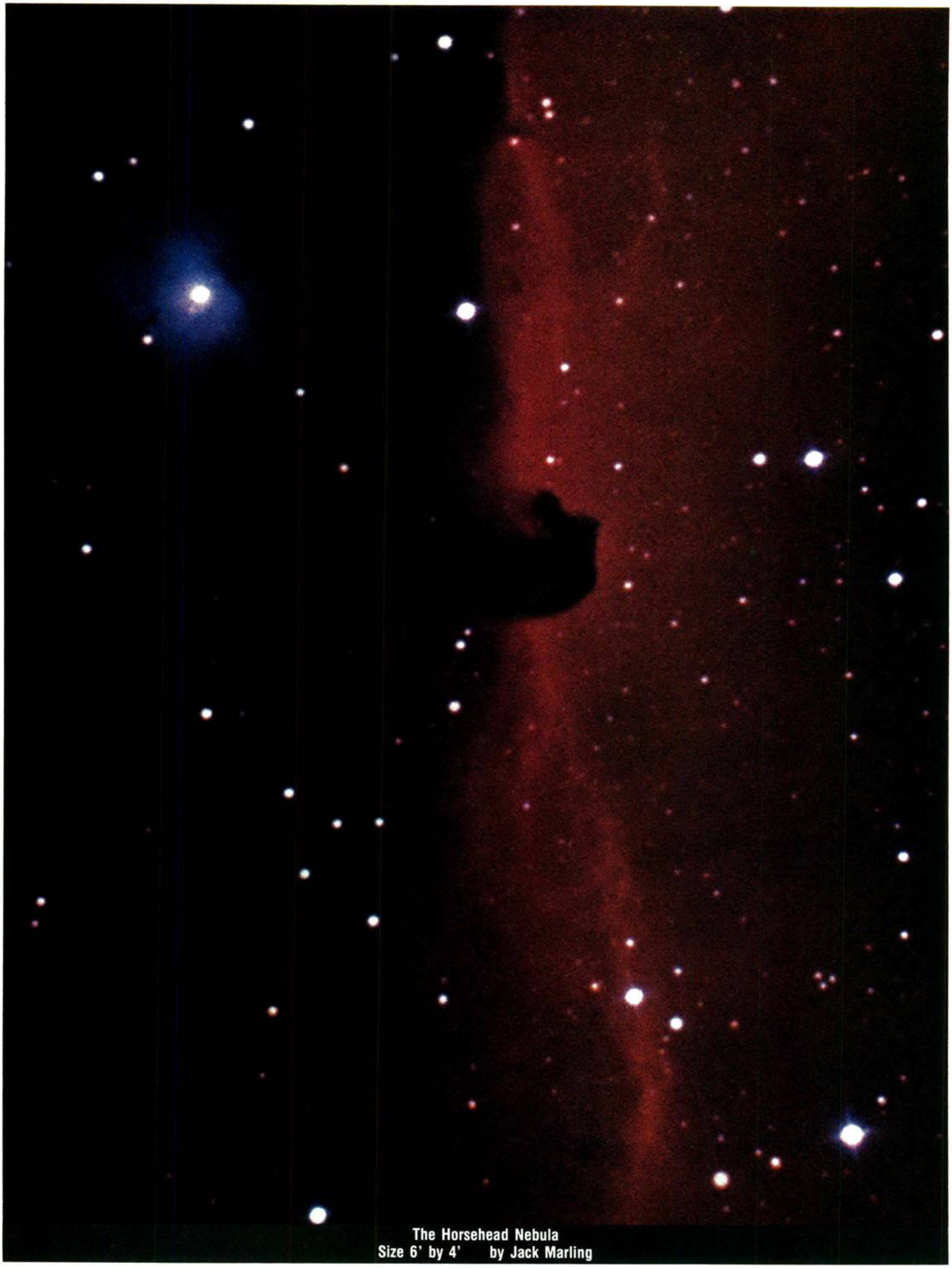
The first Pluto perihelion in almost 250 years occurred last September; therefore the planet's opposition on May 7 offers a view of Pluto about as good as anyone alive will ever see again. A simple finder chart is on page 72; we will publish a more detailed chart in our April 1990 issue as opposition approaches. You need at least an 8-inch telescope to see Pluto, and bigger apertures make the job easier and more enjoyable.

Pluto is a slowly moving, starlike dot of light at 13.6 magnitude among the stars just south of the celestial equator, where Virgo, Libra, and Serpens Caput join. It lies 3.5° southwest of the globular cluster M5. ☐

1990's Dark Sky 'Windows'



When will the skies be dark and moonless this year? The dark bands crossing the chart between the sunset line on the left and the sunrise line on the right show the dates and standard times for when the Moon will be out of the sky.



The Horsehead Nebula
Size 6' by 4' by Jack Marling

Stalking the Elusive Horsehead

With a moderate-sized telescope, a black sky, and a little patience, you can find one of the sky's most beautiful deep-sky objects.

by David Higgins

Orion's legendary Horsehead Nebula represents the greatest challenge of all for deep-sky observers. Unrivaled as a tough object for visual observers, the Horsehead is far more elusive than photographs suggest. Although relatively easy to capture on film, this small, dark nebula consistently evades those who wish to see it with eyes alone.

The Horsehead is a cloud of dust particles suspended in space just south of Orion's belt. Dark nebulae like the Horsehead are strewn throughout the spiral arms of the Milky Way. Because they don't emit light, dark nebulae are visible only when they block our view of something bright behind them. In the case of the Horsehead, the nebula lies directly in front of a dim strip of emission nebulosity catalogued as IC 434. The Horsehead, itself catalogued as Barnard 33, is visible as a tiny, dark notch in the eastern edge of IC 434.

The Horsehead picked up its nickname in the nineteenth century because, well, it *is* shaped like a horse's head. Ever since its discovery, the allure of seeing such a challenging object with a curious and distinctive shape has drawn thousands of backyard astronomers to the eyepiece in search of the Horsehead. Observer's reports have proven that the Horsehead can be seen with a telescope as small as 5-inches in aperture, although more typically it remains a challenge for those armed with 12-inch or even 16-inch telescopes. Key factors in spotting the Horsehead are observing under a perfectly black sky, pinpointing the exact location of the nebula, achieving maximum eye sensitivity through dark adaptation, and viewing with a nebula filter.

What Is the Horsehead, Anyway?

The Horsehead Nebula is a vast cloud of gas intermingled with dark dust particles; the particles are roughly the size of those in cigarette smoke. Most dark nebulae contain predominantly hydrogen gas and are typically 10 or 20 percent dust.

Most dark nebulae are not so easily visible as the Horsehead. For astronomers to detect a dark cloud, it must lie along a line of sight that places it directly in front of a reasonably dense background of bright material, like a rich starfield or a bright nebula. The Horsehead is visible only because it blocks light from the emission nebula IC 434.

Although it's easy to think of celestial objects as static, particles in nebulae are in a constant state of motion. Only the Horsehead's large physical size and great distance make it seem changeless. But change will come given time: Over the course of several thousand years, the object we know as a Horsehead may very well transform itself into a not-so-glamorous mule.

Orion — Here I Come!

Before heading outside to observe the Horsehead, study the region of central Orion carefully using the map on page 84. IC 434 lies embedded in a large area of hydrogen gas and dust that stretches from Alnitak (Zeta [ζ] Orionis) south to Rigel. Long-exposure photographs show that this area is very rich in gas and dust. However, most of this nebulosity — with the exception of the Orion Nebula and the Horsehead region — is beyond visual detection.

Orion's belt is composed of three stars: Alnitak, Alnilam (Epsilon [ε] Orionis), and Mintaka (Delta [δ] Orionis). Alnitak, the easternmost star, is surrounded by nebulae. IC 434 is aligned north-south, begins at Alnitak, and extends 1° to the south. The Horsehead Nebula lies about 40′ south of Alnitak. The Horsehead measures 6′ by 4′ and is the darkest part of a cloud of dark nebulosity that borders IC 434. Other nebulae lie in the immediate area: for example, NGC 2024 is a large circular nebula immediately east of Alnitak that is bisected by a broad lane of dark nebulosity. This object serves as a good test before you try for the Horsehead. NGC 2024 is far brighter than IC 434; so if NGC 2024 is easily visible, conditions are favorable for spotting the Horsehead. Another test object is the small, roundish reflection nebula NGC 2023, located about 25′ south of Alnitak. This nebula surrounds an 8th-magnitude star and is far easier to see than its neighbor IC 434.

The simplest way to find the Horsehead is to start by zeroing in on NGC 2023. With a 6-inch or larger scope and a medium-power eyepiece, aim your scope 25′ southeast of Alnitak and you will see a slight haze surrounding an 8th-magnitude star. (Make sure that you're using a high enough magnification to keep Alnitak outside of the field of view. Otherwise, the bright star's glare will interfere with seeing NGC 2023.) After identifying NGC 2023, fix your gaze approximately 10′ west of the nebula's central star and you'll see a lone, 9th-magnitude star. Now look about 5′ south of this star; you'll be staring directly at the position of the Horsehead Nebula.

Hints for Horsehead Hunting

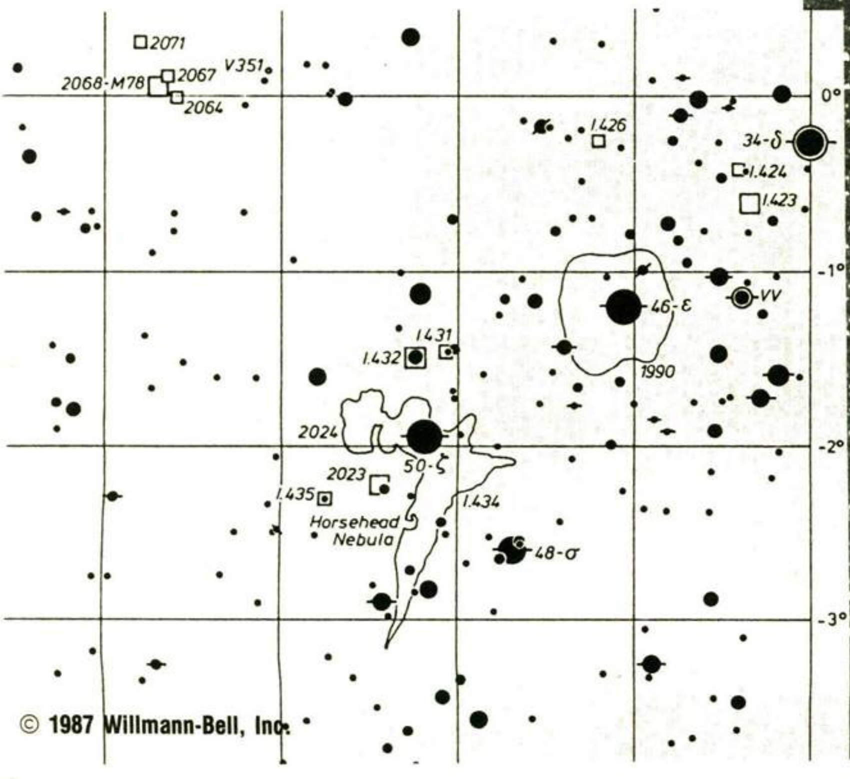
If at first you don't see the Horsehead or at least the ghostly glow of IC 434, you can employ a few tricks of the trade to heighten your chances of success. First, give your eyes ample time to fully dark adapt to their maximum sensitivity. This generally means "warming up" with some casual observing for a period of half an hour or more.

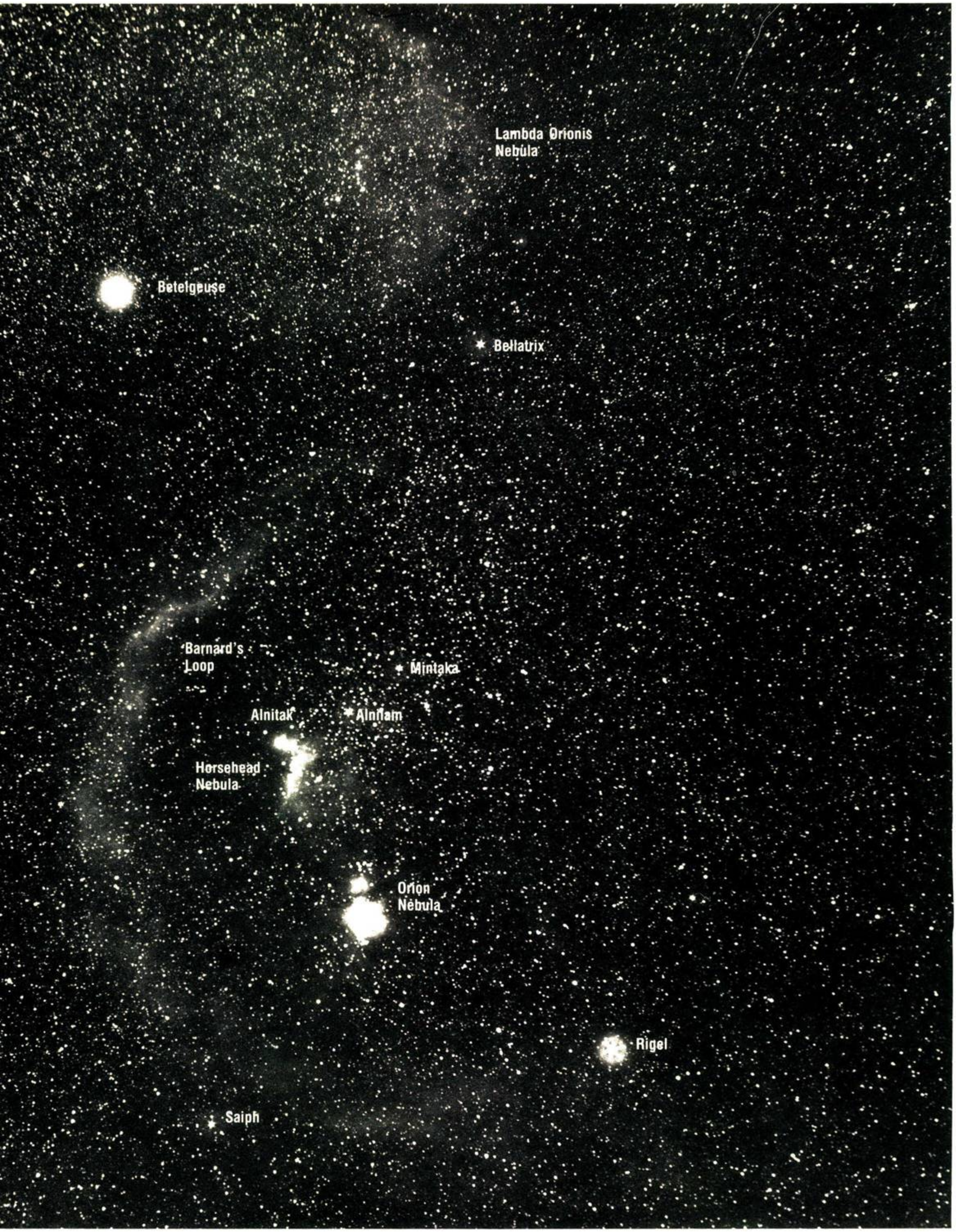
To provide the best possible dark adaptation, try to keep your exposure to the Sun at a minimum for a day or two prior to observing. Additionally, use averted vision when you're searching for the Horsehead. A gradual glance off to the side of the telescope's field lets you see an object in the field center with your rods, your eye's specialized faint-light receptors. This can make the difference between seeing an extremely faint object and not seeing it.

Make sure that your observing site is very dark and that you attempt to observe the Horsehead on nights of excellent seeing and transparency. Also, your best Horsehead observing will be possible when central Orion is on or near the meridian, at its highest possible elevation from your site. At such a time you'll be looking through the least possible amount of particles in Earth's atmosphere, minimizing the interference with the precious few photons traveling all the way from IC 434.

Rosette Nebula
ORION

PINPOINTING THE HORSEHEAD is no easy task. Start at Alnitak, the easternmost star in Orion's belt. From there, move 30′ south: the Horsehead lies 5′ east of a faint pair of stars. Photo by Greg Field. Map copyright 1987 Willmann-Bell, Inc.

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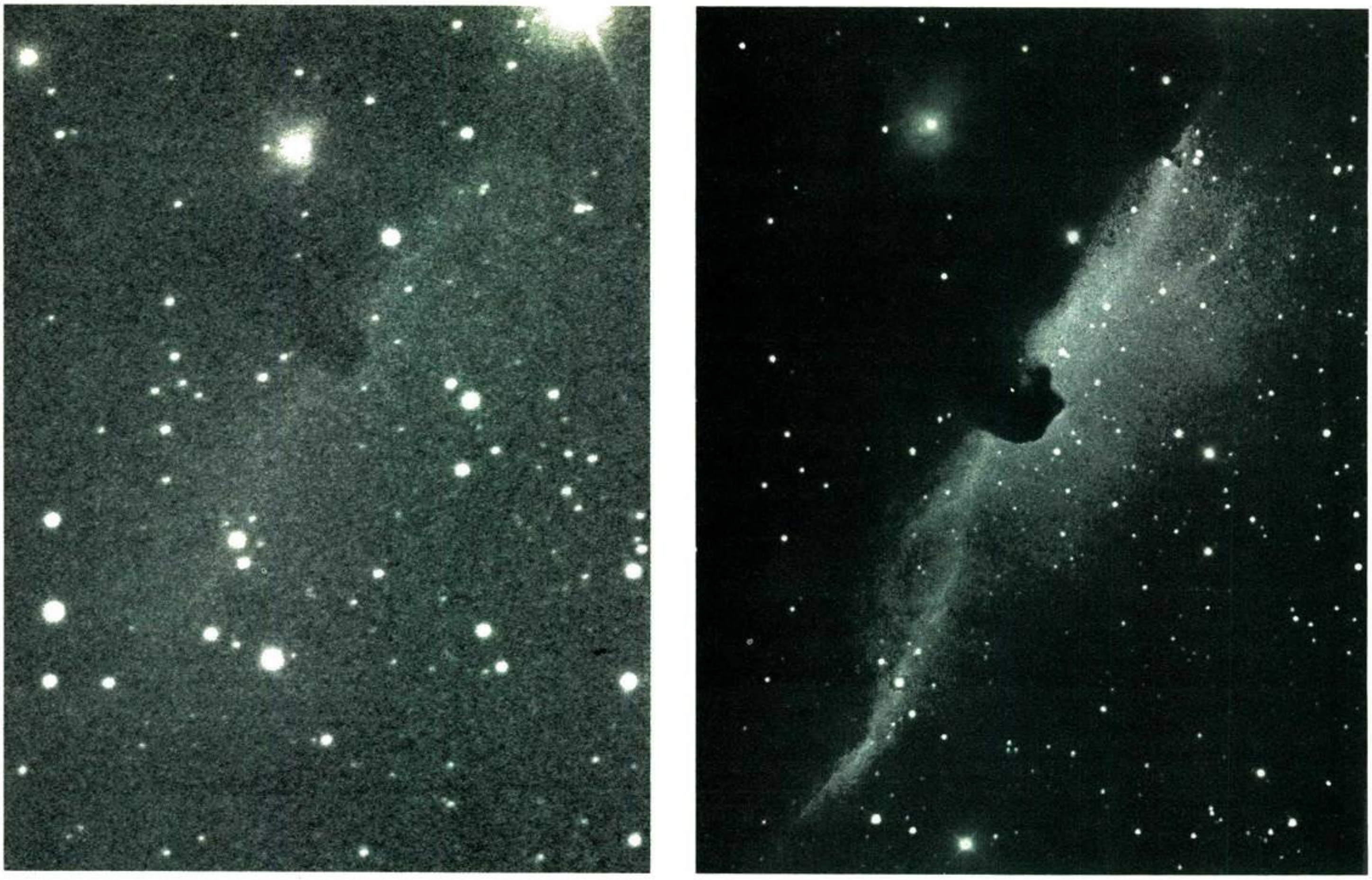
Betelgeuse
Bellatrix
Barnard's Loop
Mintaka
Alnitak
Alnilam
Horsehead Nebula
Orion Nebula
Rigel
Saiph



SIMULATED VIEWS of the Horsehead Nebula dramatize the effect of large-aperture viewing. A 10-inch telescope barely detects the Horsehead (left), whereas an 18-inch provides a reasonably detailed view (right). Photos by Hal Jandorf (left) and Jack Newton.

To better the odds of seeing the Horsehead, use a nebula filter. Specifically, the Lumicon H-β filter is designed to boost contrast on faint nebulae like IC 434, giving observers with small telescopes the best possible chance to see a faint object. Under ideal conditions the Horsehead is visible without a filter, but using the H-β filter will increase your chances of success.

Seeing the Horsehead

After you recognize the faint glow of IC 434 and pinpoint the Horsehead, the level of detail you'll see depends on your telescope, observing experience, and the quality of the night. Telescopes in the 6-inch to 10-inch range show an extremely faint wisp of nebulosity, visible only by averted vision, less than 30′ in length. Under average conditions the faintness of IC 434 may make you wonder if you can see it at all.

The Horsehead will most likely appear as an indistinct nick 1′ long cut into the central, eastern portion of the band of nebulosity. Large telescopes make seeing the Horsehead much easier. A 14-inch or 16-inch telescope shows IC 434 as a faint strip of nebulosity nearly 60′ long. The Horsehead appears like a small, square box, without the familiar features — nose and mane — that stand out in photographs. Only in extremely large backyard scopes — 20-inchers or larger — will some hint of the horse's nose be visible.

Increased contrast from using the H-β filter greatly improves the view. With small telescopes it yields a view of IC 434 that leaves you certain you actually saw it. The edges of IC 434 are no longer indistinct: they are well delineated from the surrounding starfield. In telescopes of 16-inches and larger, IC 434 is much more easily visible, which in turn makes the Horsehead stand out without too much trouble on dark nights. With a 17.5-inch scope on a good night, the filter allows you to see the Horsehead plainly with direct vision.

A filtered view through my 24-inch scope shows some shape in the Horsehead; the head component appears rounded on its southwestern side and slopes toward the horse's nose. The southern side, or mane, is the darkest part of the nebula. The horse's neck widens as it fades into the dark cloud that extends eastward. On nights of superb transparency, I can glimpse several faint field stars visible immediately north of the nose.

The final word on Horsehead hunting is experimentation. Reports from experienced and reliable observers establish that in some cases the Horsehead is visible in a 5-inch scope, in others invisible in a 40-inch scope. Try different eyepieces and telescopes to give yourself a wide choice of views of the Horsehead and IC 434. Some eyepieces will show more detail than others. And experiment with filters, dark adaptation, and averted-vision techniques.

On top of everything, keep searching. If you do, you'll see the Horsehead for yourself. And after you see the Horsehead, other deep-sky challenges will no longer seem quite so intimidating. □

David Higgins is central coordinator of the National Deep Sky Observers Society and a contributing editor to Deep Sky *magazine. He lives in Krebs, Oklahoma.*

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In Pursuit of the Perfect Planet

To take above-average photographs of the planets, you need patience, diligence, and plain luck — and you need to know when *not* to listen to the experts.

by Donald Parker, as told to Robert Reeves

Few astrophotographers are so proficient with camera and telescope that their photos appear routinely in astronomy publications and are used for scientific research. Donald Parker, however, is an exception. A physician from Coral Gables, Florida, Don is considered by many amateur astronomers to be the leading planet photographer in the country. He is coauthor (along with Charles Capen and Thomas Dobbins) of Observing and Photographing the Solar System *(Willmann-Bell, Inc., 1988) and is also a senior Mars recorder with the Association of Lunar and Planetary Observers (ALPO).*

Recently Don talked with Robert Reeves about his experiences (both good and bad) as a planetary photographer.

I began observing, drawing, and photographing the planets with small homemade telescopes about 1950. I soon discovered that I hate drawing!

Today, almost forty years later, many things still excite me about solar system photography, but my favorite pursuit is patrol photography of Mars and Jupiter — i.e., systematically monitoring these planets for changes in surface features. I love knowing that I have produced unique records of ephemeral planetary features. No one will ever again see the planet exactly the way it appears when I shoot it. There is also the excitement of exploring and always a chance of discovering some new planetary feature or outbreak of activity.

I was drawn to photography because I always wanted to share what I saw through the telescope with others. I think this is the underlying motive of most astrophotographers. But after meeting Charles Capen, my interest in planetary photography grew even more. A long-time Mars recorder for ALPO, Capen was probably the last of the great observational astronomers. His knowledge of Mars and its observational history was extensive. He loved teaching amateurs and felt strongly that amateur contributions are important to astronomy.

Capen stressed that professional astronomers need quantitative data to study planets and that one way amateurs could get this data was through photography. Capen was an accomplished astrophotographer and terrestrial photographer, and what he taught me quickly elevated my "pastime" to a discipline. His untimely death in 1986 touched many amateur and professional astronomers.

I currently use two telescopes, a 16-inch f/6 and a 12.5-inch f/6.5 Newtonian, for my planetary work. My scope is permanently mounted in a covered observatory. When we built our house, I added an 8-foot-square concrete deck off our second floor bedroom. The deck rests on two pilings that extend 22 feet into coral rock, so it is rock steady. A simple sliding roof weatherproofs the instrument.

DONALD PARKER demonstrates the tracking of his 16-inch f/6 Newtonian that he uses for photographing the planets.

This arrangement is most convenient, allowing me to set up in less than five minutes. This is important in planetary patrol work, where one must observe or photograph the planets every night that is steady enough. Here in south Florida, this means about two hundred nights per year. Unlike most other parts of the United States, when the wind blows here, the "seeing" becomes very steady. In 1984 fellow ALPO Mars recorder Jeff Beish and I observed Mars on 293 nights. I often prayed for rain!

Perhaps because I had such a good teacher in Charles Capen, I enjoy passing along what I've learned to interested amateur astronomers. One thing beginners always want to know about is film: "What kind do you use and how do you process it?" I strongly recommend color slide films in the ISO 100-200 range. You will get some good shots with little grain and avoid darkroom hassles.

I buy most films in 100- or 150-foot rolls (bulk film is less expensive in the long run than buying it by the roll). I do all my own black-and-white developing and printing as well as color printing. I also do my own copy work and a fair amount of composite printing. On occasion I do unsharp masking, although I avoid that whenever possible. For consistent quality work I feel that you must do your own printing, although I have seen some good Mars shots from drugstore processing of Kodak's VR-series of color print films.

One problem with high-resolution photography of the Moon and planets is finding a film and developer combination that will yield acceptable film speed with a good contrast range. For black-and-white film the Tech Pan and Rodinal combination I use goes a long way to this end, but I am still experimenting.

I started hypering my own film a couple of years ago when Mike Reynolds, an amateur astrophotographer in Jacksonville, Florida, suggested that we try hypered film in planetary work, despite the prevailing attitude against using hypered film for planets. It has worked so well that I use it all the time for Mars, Saturn, and Jupiter black-and-white photography. It not only more than doubles film speed, but significantly increases contrast. I do all my hypering in a tank that I built from a $39 Presto pressure cooker; it holds six reels of film.

Many people are shocked to discover that I use hydrogen — a volatile gas — to hyper my film. But being an anesthesiologist, I am accustomed to handling explosive gases. Hydrogen, being so much lighter than air, is actually less combustible than gasoline and hypers film in a couple of hours rather than days. It also increases film speed more than forming gas does. Using hydrogen is also very macho and keeps people out of my garage!

I have three basic tips for aspiring astrophotographers. First, pay attention to details such as telescope collimation, tracking, focus, fresh chemicals, and the like. Second, take careful notes on everything you do so when you luck out, you'll know why. Third, don't expect the "experts" always to be right. Although I wrote the chapter on photography in *Observing and Photographing the Solar System*, I have managed to make just about every mistake I had warned about in the book. Two very embarrassing moments stick out in my mind.

One occurred two years ago when I went to Macon, Georgia, to give a talk for Astronomy Day. On the morning following the talk, the crescent Moon occulted Venus. As the "expert" on photography, I photographed the event with my host, Mike Hood. I had given the other Macon Club members exposures to use at the previous night's meeting. Unfortunately, I made a major mistake in the exposure time calculations, using the luminance value for the Full Moon. Even with bracketing the slides were virtually blank, and I got some "black hole" jokes from my friends at the photo lab. Fortunately, I was out of town on the next stage. I hope the folks in Macon who used my suggested exposures think that they must have done something wrong. Indeed they did — they listened to me!

Another goof was when I demonstrated to some visitors how to photograph Jupiter with infrared film. I developed the film for them on the same evening but left the radio in my darkroom on. The little red stereo LED fogged the entire roll just as if I had left it in the Sun. These mistakes were mostly caused by overconfidence — something no astrophotographer can afford to have.

Fortunately, I can take refuge in a few successes. I suppose my "crowning achievement" is being the second person to win ALPO's Walter H. Haas

PARKER RECORDED MARS' dark surface features and a tiny south polar cap a month before its 1988 opposition.

Award in 1986. (Charles Capen was the first in 1985.) I was given the award for my contributions to planetary photography.

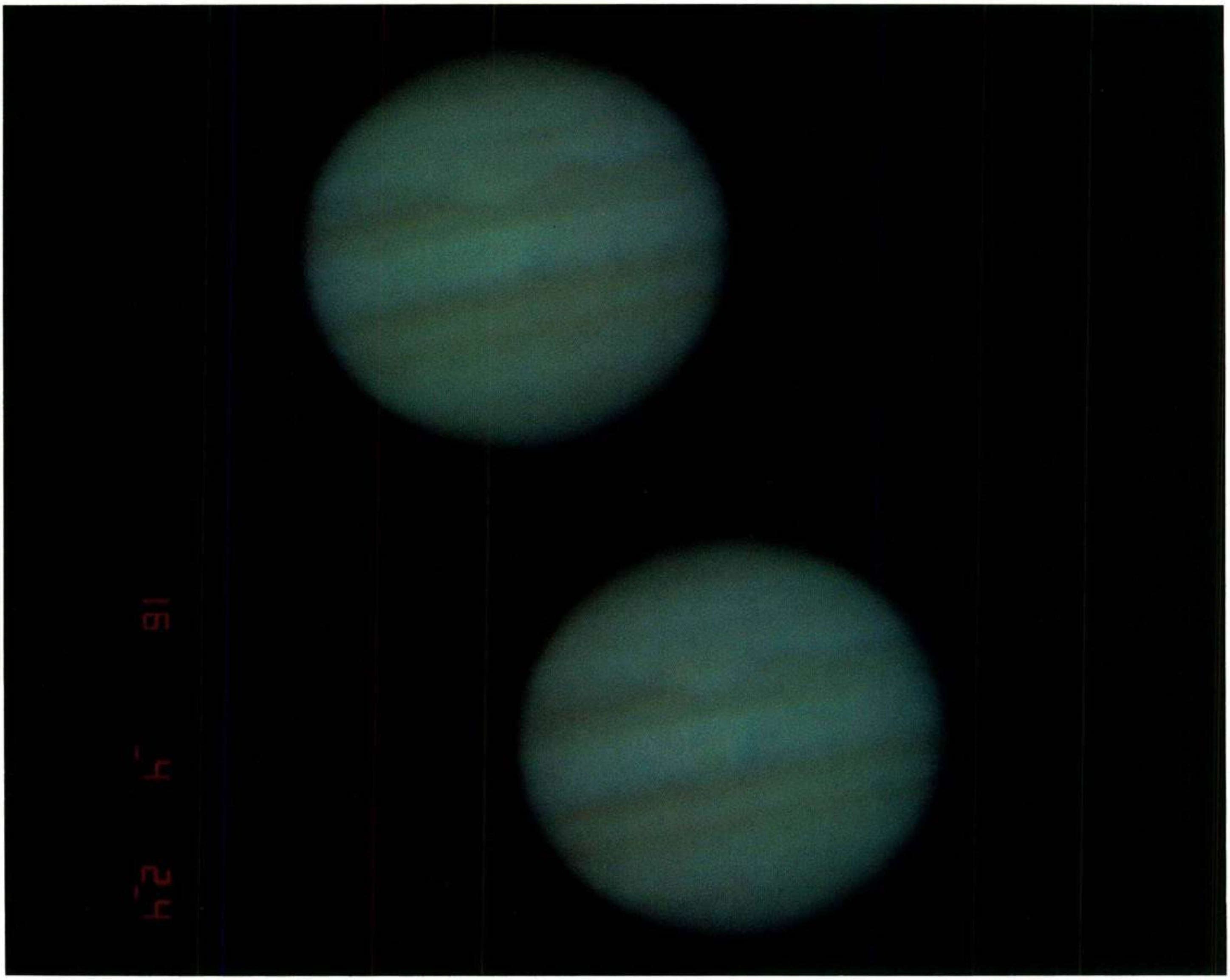
Two other thrills are related to my Mars work. In 1986 I went to Cerro Tololo, Chile, for three weeks to photograph Mars for Lowell Observatory's International Planetary Patrol. And this year Jeff Beish and I, with astronomers Leonard Martin of the Planetary Research Center at Lowell Observatory and Phillip James of the University of Missouri, were coauthors of the paper "Telescopic Observations of Mars in 1988." This paper was presented at the fourth International Conference on Mars in Tucson last January. Jeff and I were invitited to attend the conference and present the data from the International Mars Patrol. It's a great honor for amateurs to be invited to such a high-powered meeting, let alone be coauthors on a paper.

The most exciting work I'm currently involved in is an ongoing study, the result of my mentor, Charles Capen, insisting that Jeff Beish and I work on long, tedious projects. In 1979 I began performing hundreds of micrometer measurements of Mars' north polar cap regressions (the polar cap shrinks and grows depending on the Martian season) while Jeff started a computerized catalog of 13,000 Martian clouds observed by International Mars Patrol (IMP) astronomers since 1964. Analysis of these studies, combined with seemingly unrelated observations made by other International Mars Patrol members, have revealed that the Martian climate is variable and underwent a warming trend during the early 1980s. There may also be a correlation with a similar trend on Earth.

The beauty of these studies is that neither Jeff nor I knew what to expect when we began them, although we are sure Capen did. It is a pity that he did not live to see the results. This Mars meteorology study is what science is all about — many hours of tedium, downright discomfort, and a healthy dose of serendipity.

The bottom line is that if you wade in, get your hands dirty, and report your results honestly you will almost certainly make discoveries or at least contributions. Organizations like ALPO, the International Amateur-Professional Photoelectric Photometry (IAPPP), and the American Association of Variable Star Observers (AAVSO) not only provide amateur astronomers with an outlet for their contributions, but also a valuable repository of observations that professionals can tap

JUPITER'S EVER-CHANGING DISK is a fascinating photographic study. Parker's databack (in red) gives the day (the first number) and the UT for each exposure.



into.

You never know when you might make a discovery. In fact, sometimes you can make a discovery and not even realize it. For example, eleven years ago I took what I considered to be a rather poor-quality, unremarkable blue-light photo of Jupiter. The seeing was not especially good, so the photo was not as sharp as hundreds of others I have taken. Nevertheless I submitted it to ALPO. Much to my surprise, I found my name in an International Astronomical Union telegram as codiscoverer of the 1979 South Equatorial Belt disturbance — an outburst of violent activity heralded by a brilliant white spot in the belt. My photos were also apparently important in providing quantitative data on the rotation rate and development of this disturbance.

Other memorable photos were shots of the Martian dust storm in June 1988 and the movement of the second Martian dust storm from November 28 to December 1, 1988. None of these photos would be classified as award winners, but they are about the only proof that these storms occurred. Most astronomers were "weathered out," and the storms subsided before they could get decent shots. In both cases Mars had a small apparent diameter, so both the professionals and amateurs were not photographing the planet.

The moral is that amateurs should send their photos regularly to people who can analyze them, such as the appropriate recorders of ALPO, regardless of whether or not they are great photos. Every photo is a document that might yield interesting data and should not be lost in a desk drawer.

When you submit your photographs or slides, be sure that each is properly documented, especially with the date and time. This sounds simple, but Jeff Beish and I had to return nearly 5 percent of the 1,000-plus Mars photos we received last year, because they were submitted without dates and times. Some of these were fine shots, but without the proper data they are scientifically worthless.

I think some recent developments have improved planetary observing for amateurs. The Dobsonian revolution has introduced people to the benefits of large apertures and has returned people to making their own telescopes. Recently refractors have made a comeback, indicating that people are beginning to appreciate quality images once again. New film emulsions and electronics have also had a major impact. All these improvements have led to a situation where amateurs today possess instrumentation capable of performing professional work.

The most significant development, however, is the growing cooperation between amateurs and professionals, evident in such "pro-am" organizations as the IAPPP and ALPO.

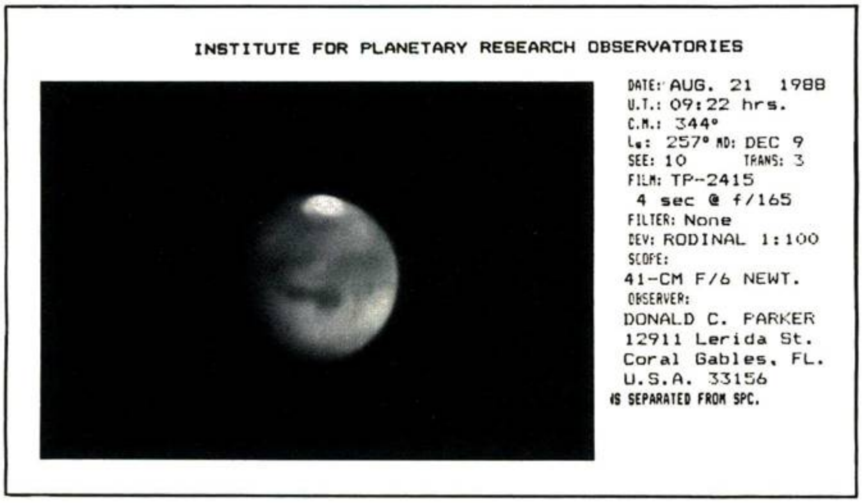
During the 1988 Martian opposition there was a vast improvement in the quality of Mars photos over previous years. This is probably due to greater emphasis on optical quality, collimation, and larger apertures. A major factor is the increased use of fine-grained Tech Pan film and better color emulsions. Another reason for these improved photos, however, is that Mars was bigger, higher, and easier to photograph in 1988. Hopefully, astrophotographers will continue shooting during future apparitions when the planet is not as well placed in the sky.

I tell observers not to be afraid to send your photos to the appropriate people for analysis. Astrophotographers should get tough: "If I go through the trouble to take the photos, then someone can go through the trouble of looking at them."

A major point I make to novice astrophotographers is never to be satisfied with your results. You can be pleased, but develop an attitude that there is always room for improvement. In a way, a successful astrophotographer is like a gunfighter — there is always someone out there who is going to take a shot at you (no pun intended). This is healthy and can only help improve photographic quality and lead to new techniques and equipment.

There are two developments in astrophoto technology that I am looking forward to. There are new superfast, virtually grainless films with excellent acuteness and contrast range. Such films exist but are not yet available. Another technological development is an easy, fast, and relatively inexpensive way to make quality color prints from slides. Agfachrome Speed paper was a good start in this direction, but it is no longer marketed.

I also hope to one day be able to image Mars and the other planets electronically rather than photographically. I feel that in two to five years such imaging will routinely be available to the amateur. Three observers, Alan McFarlane in Seattle, Dave Brewer in Florida, and John Sanford in California, are currently doing superb video work. The members of the Santa Barbara Astronomy Club are also doing CCD imaging for the International Mars Patrol. I am encouraging all these people to develop their techniques so that I can apply their mistakes to my continuing education in astronomy! ☐



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DATE: AUG. 21 1988
U.T.: 09:22 hrs.
C.M.: 344°
$L_\odot$: 257° MD: DEC 9
SEE: 10 TRANS: 3
FILM: TP-2415
4 sec @ f/165
FILTER: None
DEV: RODINAL 1:100
SCOPE:
41-CM F/6 NEWT.
OBSERVER:
DONALD C. PARKER
12911 Lerida St.
Coral Gables, FL.
U.S.A. 33156
IS SEPARATED FROM SPC.

THE MORE DATA THE BETTER. Parker documents each photo for research purposes. The information shows that this Mars photo was taken August 21, 1988, at 9 hours 22 minutes UT. At that time Mars' orbital position with respect to the Sun's longitude (Ls) was 257°, making the Martian date December 9 (approaching Mars' winter solstice). Seeing conditions were 10 (excellent) and transparency 3 (the faintest naked-eye magnitude). The film used was Tech Pan 2415. The exposure was 4 seconds at f/165; no filter was used. The developer was Rodinal diluted to 1:100, and the telescope was a 16-inch f/6 Newtonian. According to Parker's observing notes, the photo records Novus Mons separated from the south polar cap.

Robert Reeves is an amateur astronomer and astrophotographer. His most recent article, "Astrophotos the Easy Way," appeared in the September 1989 issue.

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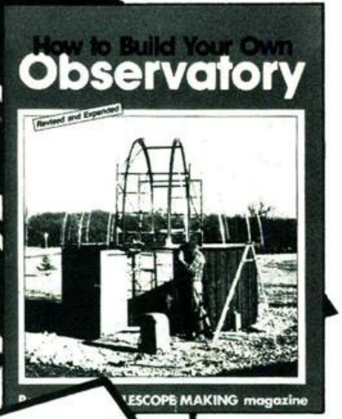
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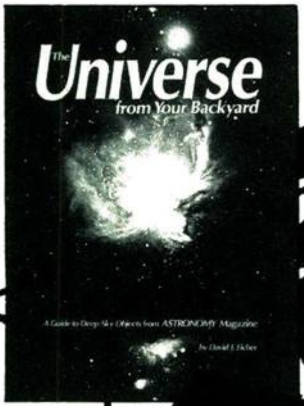
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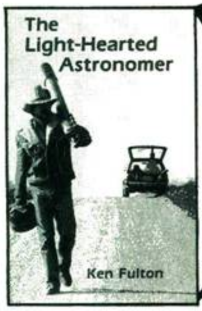
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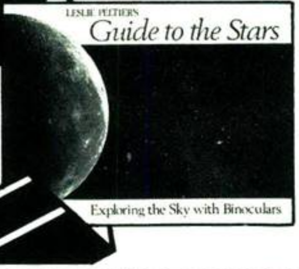
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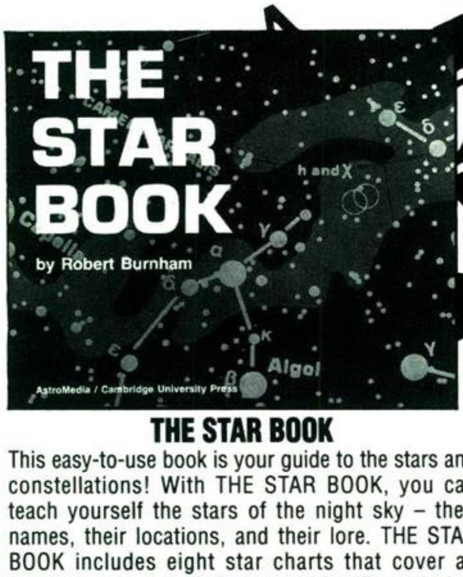
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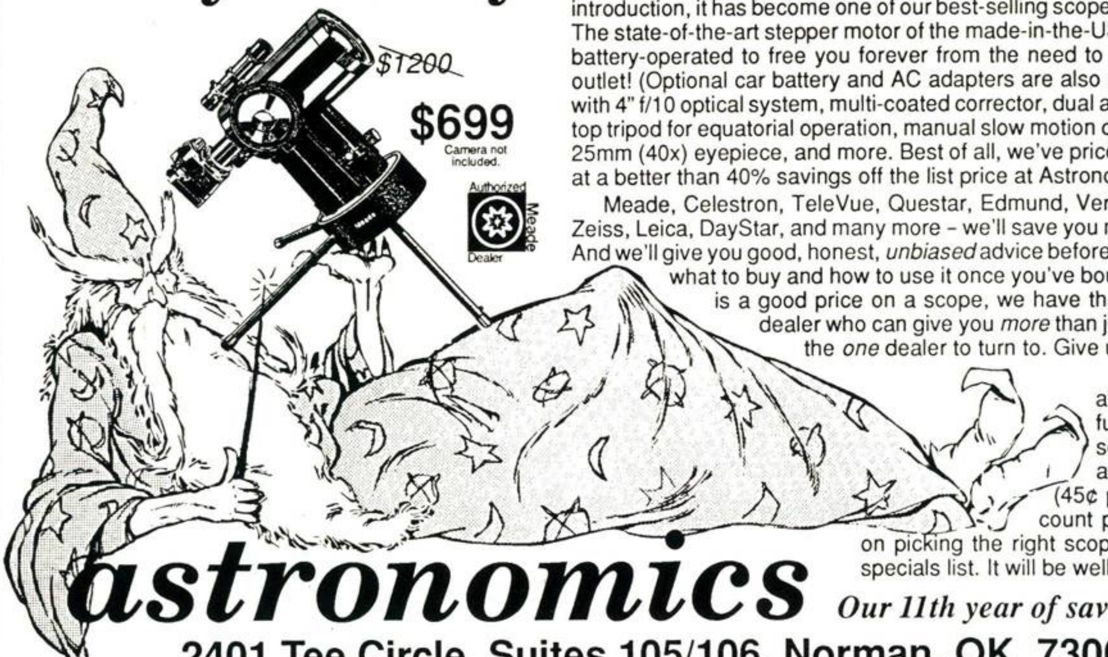
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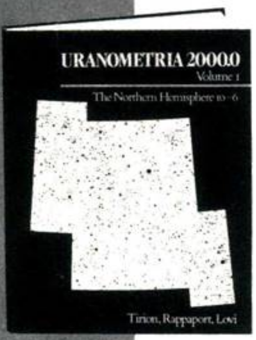

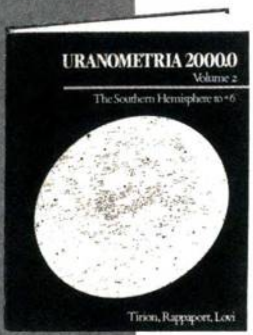

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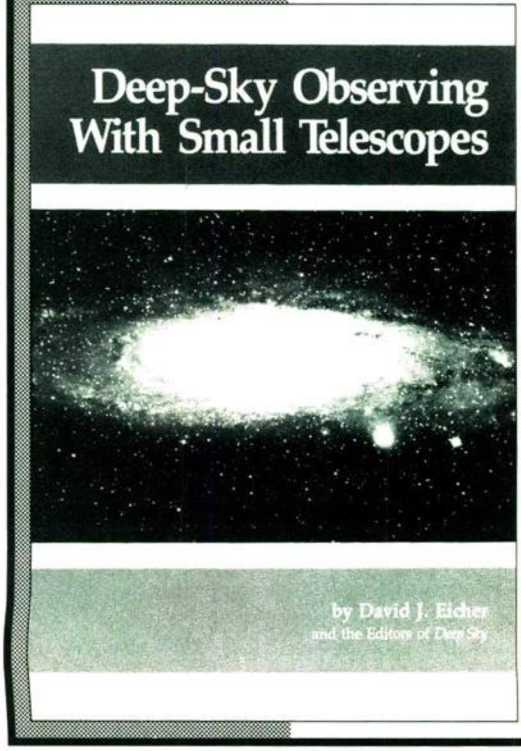

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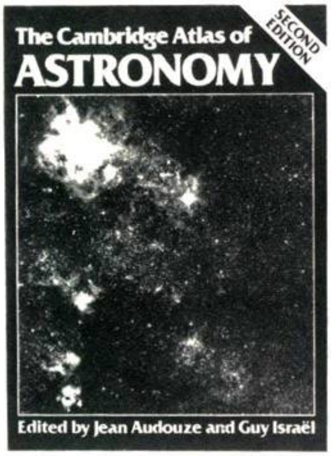
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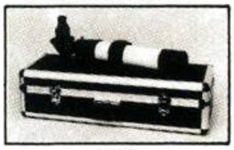

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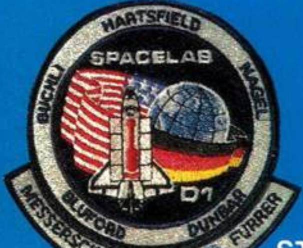
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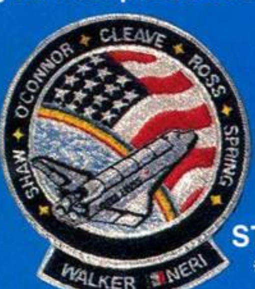
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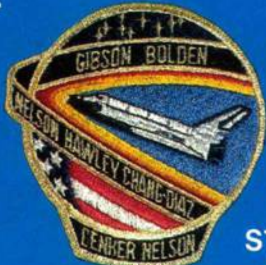
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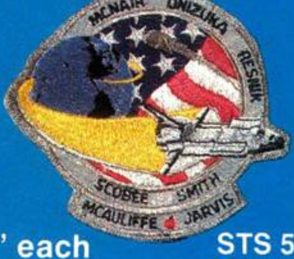
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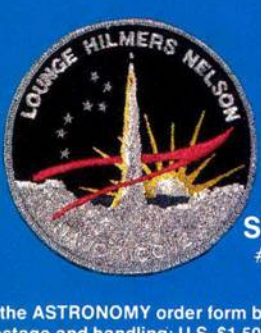
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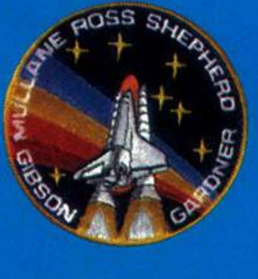
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The Six Tails of Brorsen-Metcalf

Comet Brorsen-Metcalf brightened to naked-eye visibility and displayed a multiple-component tail that stretched 8° long.

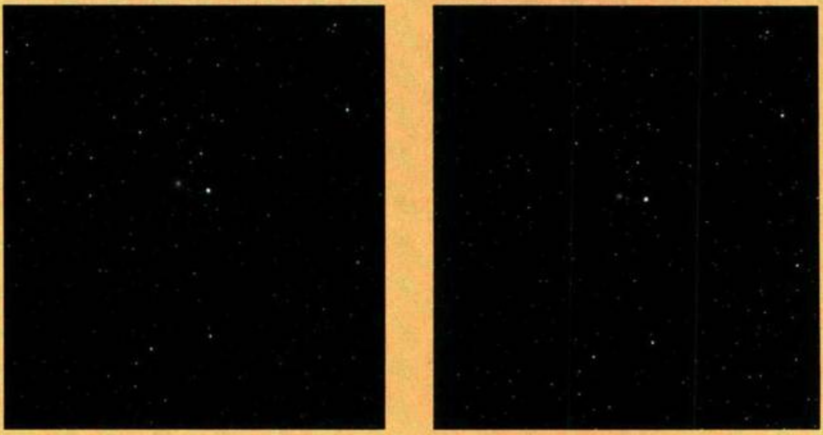
by David J. Eicher

When backyard observers think of great comets, the names Theodor Brorsen and Joel Metcalf usually don't spring to mind. However, last summer Comet Brorsen-Metcalf, a periodic comet last visible in 1919, put on a splendid show. At peak brightness, Brorsen-Metcalf shone at 5th magnitude, making it visible without optical aid. More impressively, the comet displayed a multiple ion tail that spanned 8° — equivalent to sixteen Moon diameters.

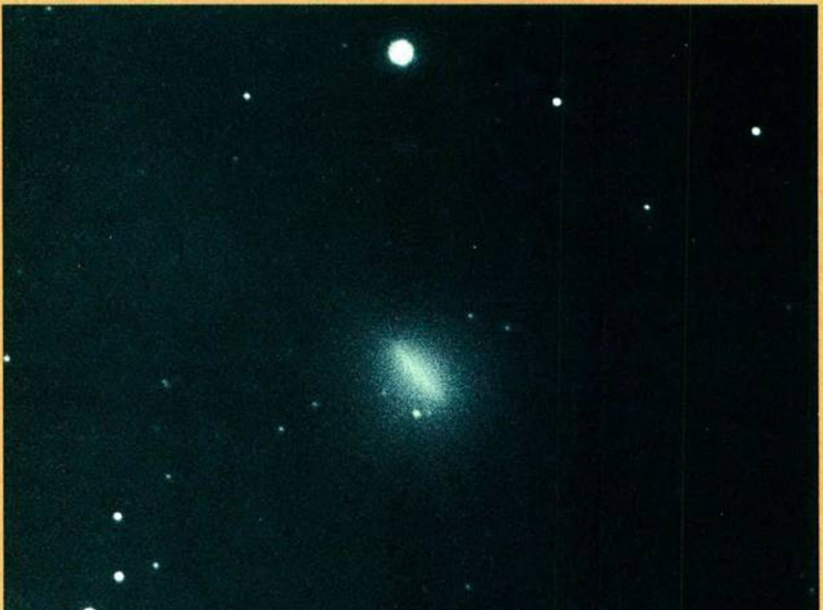
With a period of about seventy years, Comet Brorsen-Metcalf returns with a frequency almost equaling that of Halley's Comet. Uncertainties about the comet's orbit led astronomers to search for Brorsen-Metcalf without success throughout the spring and early summer of 1989. When Eleanor Helin of Palomar Observatory recovered the comet on July 4, 1989, Brorsen-Metcalf glowed at magnitude 10.

The comet's rise in size and brightness over the coming weeks was most impressive, however. By mid-August many observers estimated the comet's magnitude at 6.5, and a few observers reported spotting it without optical aid. By this time the comet's tail was nearly 2° long.

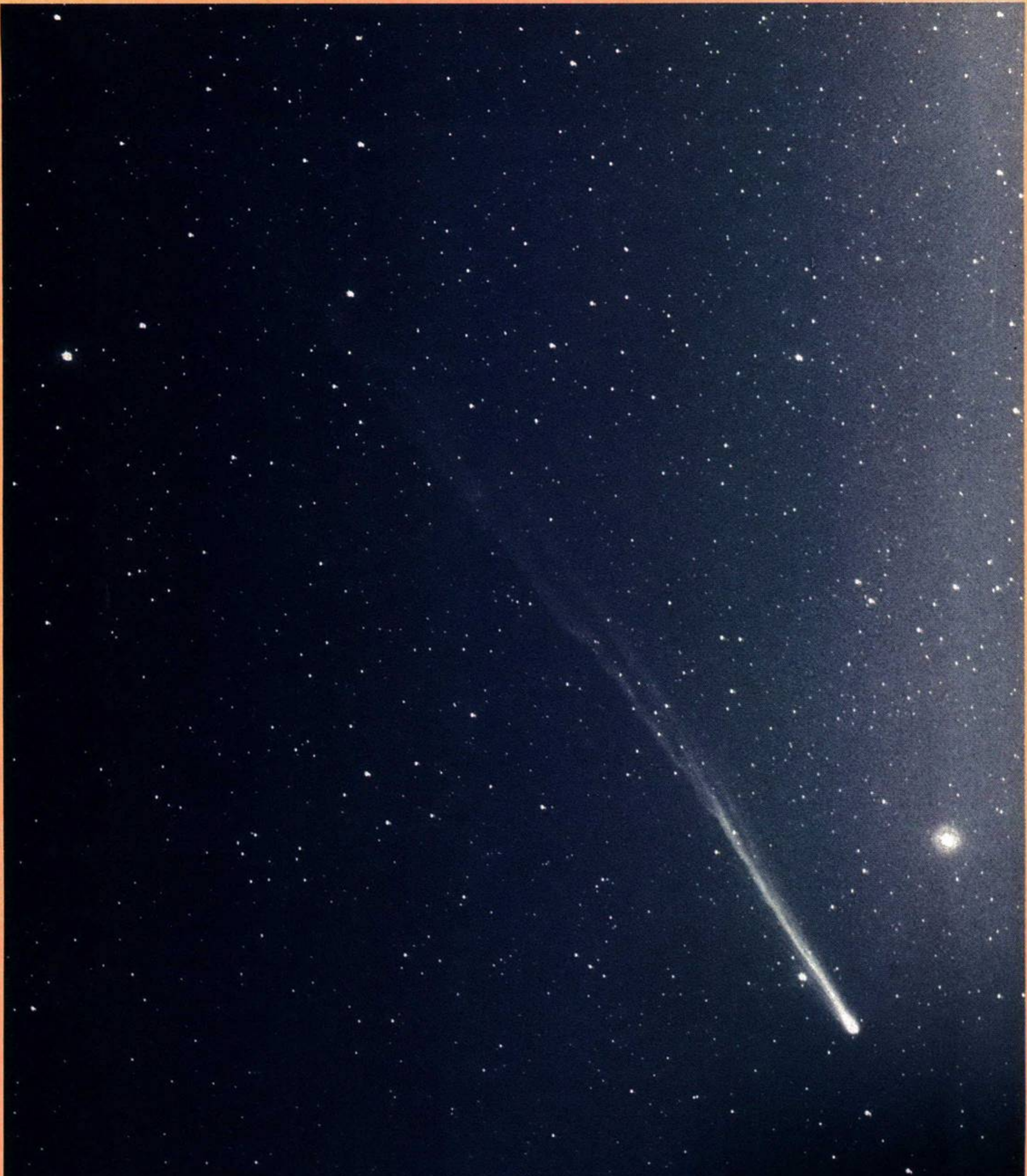
Brorsen-Metcalf reached its peak in the morning sky in early September, before slipping too close to the Sun to be observed. On September 4, Charles Morris of Pine Mountain Club, California, reported the comet's magnitude as 5.6 and recorded a tail that stretched 8°. Telescopic viewers saw subtle divisions in the comet's ion tail, and photographs recorded as many as six distinct parts of the tail. During the final days of its apparition, the comet's tail developed numerous kinks as it interacted with turbulent gusts of the solar wind. Although Brorsen-Metcalf was visible only for a brief period, its outstanding performance left those who saw it with fond memories. ☐



THE COMET'S MOTION over 25 minutes creates a pseudo-stereographic effect when two images are merged by defocusing your eyes. Martin Hale's photos were taken on July 15.



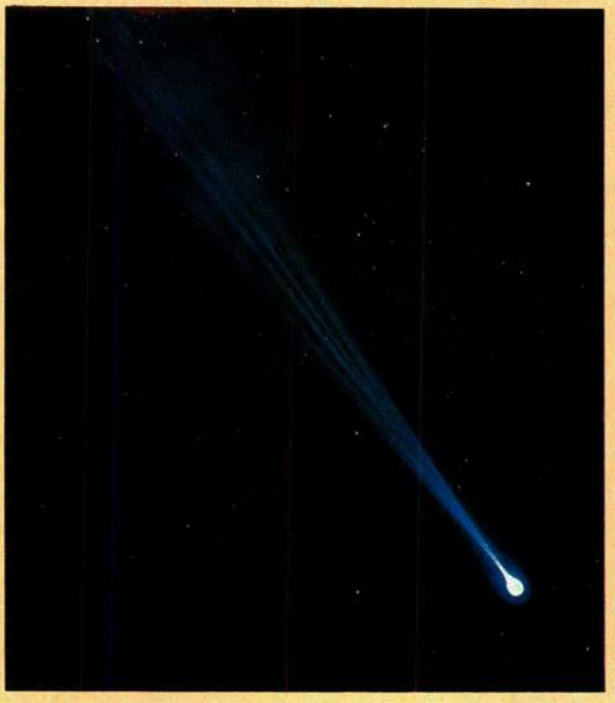
THE COMET IN AUGUST was still a blur without any sign of a tail. Jeffrey Jones guided on stars and let the comet trail, recording its motion over 10 minutes on August 5.



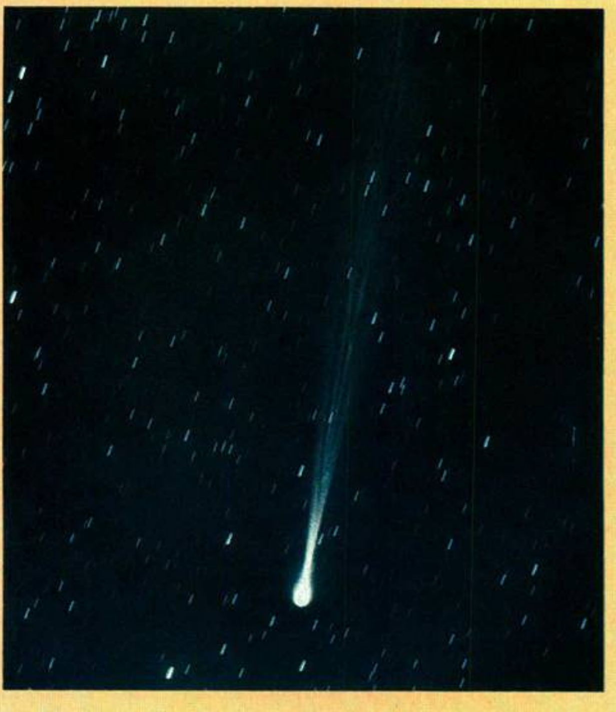
FAST OPTICS AND CONTRASTY FILM captured the comet's kinky tail. Chris Schur's 4-minute exposure, made on September 7, was made with an 8-inch f/1.5 Schmidt camera and hypered Tech Pan film.

BEST IN SEPTEMBER, Brorsen-Metcalf displayed a multiple-component tail spanning more than 10°. Michael Stecker's photo shows the comet on September 3.

THE CAMERA MIMICS THE EYE in Ronald E. Royer's photograph of the comet over the Mojave Desert on September 4.



FIVE ION TAILS were visible as parallel blue streaks on September 4. Photo by Ronald E. Royer.



TRACKING THE COMET trails stars but shows fine detail in Brorsen-Metcalf's tail. Photo by Peter Hirtle.

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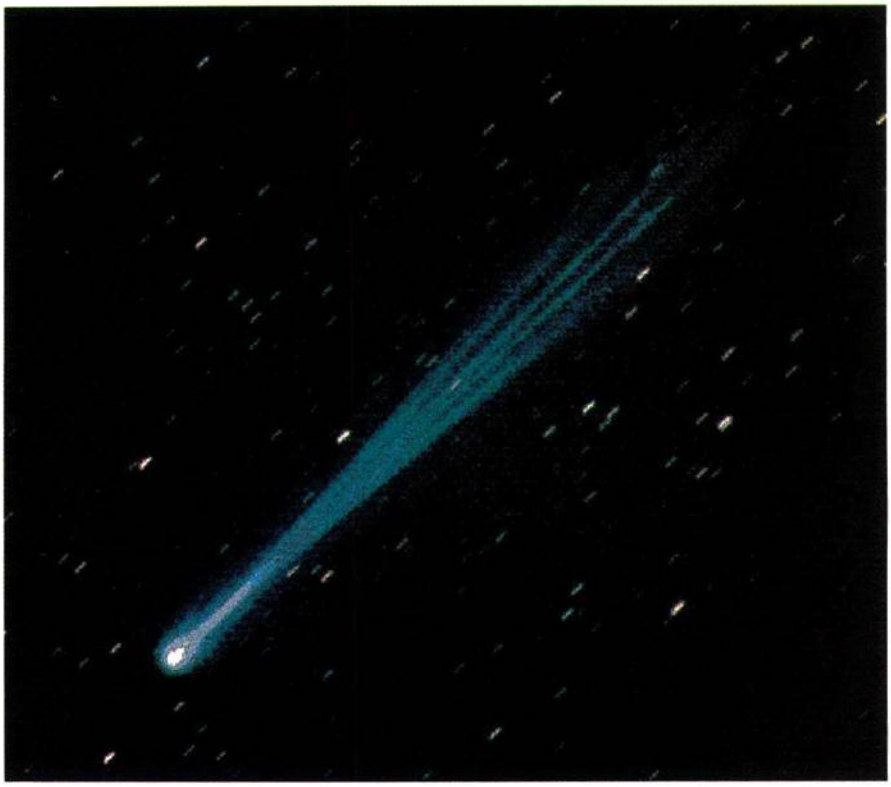
A TALE OF TWO COMETS

Comets were the name of the game in early autumn 1989 as two visitors from deep space brightened to easy binocular visibility. The periodic Comet Brorsen-Metcalf (1989o) was recovered in July, some seventy years after its last return, and reached 5th magnitude before sinking close to the Sun in the early October morning sky. The most remarkable facet of Brorsen-Metcalf's apparition was the comet's ion tail, which stretched 8° in length and consisted of up to six sharply defined components. (See "The Six Tails of Brorsen-Metcalf," page 96.)

Just as the excitement from Brorsen-Metcalf died down, another comet was waking up. At press time, predictions indicate that Comet Okazaki-Levy-Rudenko (1989r) will be the brightest comet since Halley in 1986, rising in brightness to magnitude 4.2 by November 20, 1989. The comet was discovered independently by three amateur astronomers. David H. Levy of Tucson, Arizona, spotted the comet with a 16-inch reflector on August 25, 1989. One day later Massachusetts observer Michael Rudenko found the comet with a 10-inch refractor. And on August 28 astronomers at the National Astronomical Observatory of Japan revealed that Kiyomi Okazaki had recorded the comet on a photographic plate taken on August 24. Comet 1989r became Comet Okazaki-Levy-Rudenko, a binocular object in the evening sky.

Although Levy reported the comet's magnitude as 10.6 at discovery, the comet brightened relatively quickly. Gary Kronk of Troy, Illinois, estimated its magnitude at 10.2 on August 29, and John E. Bortle of Stormville, New York, reported a magnitude of 9.7 on September 5. By September 28, Geoffrey Chester of Rixeyville, Virginia, noted that the comet shone at magnitude 8.2 and had a 10′-diameter, fan-shaped tail. On October 1, Daniel W. E. Green of Dover, Massachusetts, spotted the comet in 20x80 binoculars and estimated its magnitude at 7.8. When he photographed Okazaki-Levy-Rudenko on September 29, Paul Roques of Lowell Observatory found the tail extended 21′ on his negative, and "there was a hint of a dust tail oriented at a 45° angle from the ion tail." Roques feels that during September Brorsen-Metcalf was one of the most visually appealing comets in many years. Stay tuned for further reports on Okazaki-Levy-Rudenko as it brightens to naked-eye visibility.



A MULTIPLE TAIL is clearly visible in Michael Stecker's digitized image of Comet Brorsen-Metcalf. Stecker photographed the comet on September 3, scanned the photo into his computer, and produced this version using a Hewlett-Packard Paintjet printer.

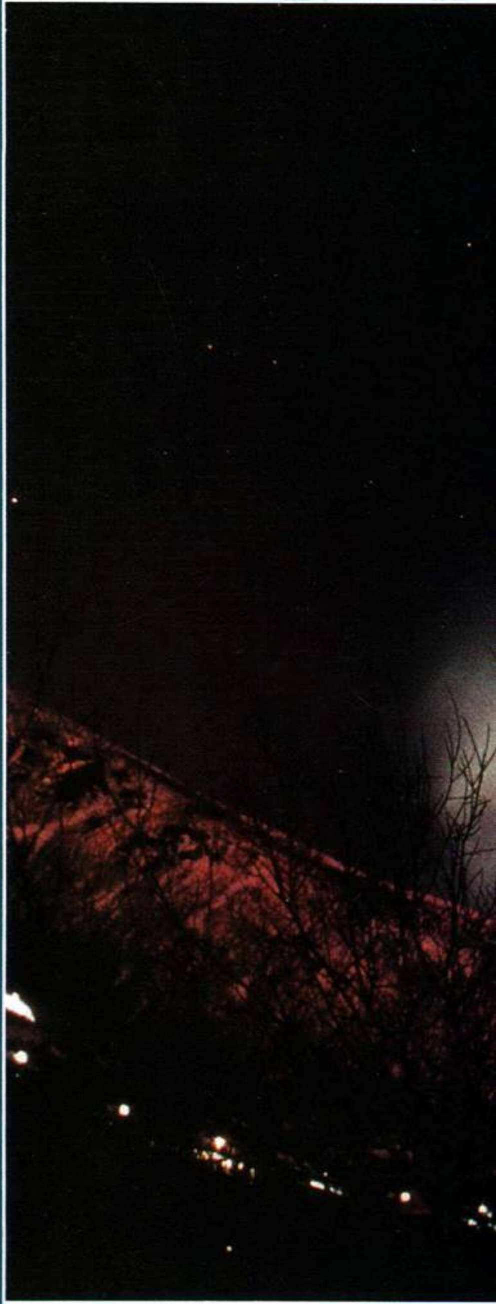
NEWLY DISCOVERED COMET Okazaki-Levy-Rudenko was a faint smudge of light when Jack Newton photographed it September 3.

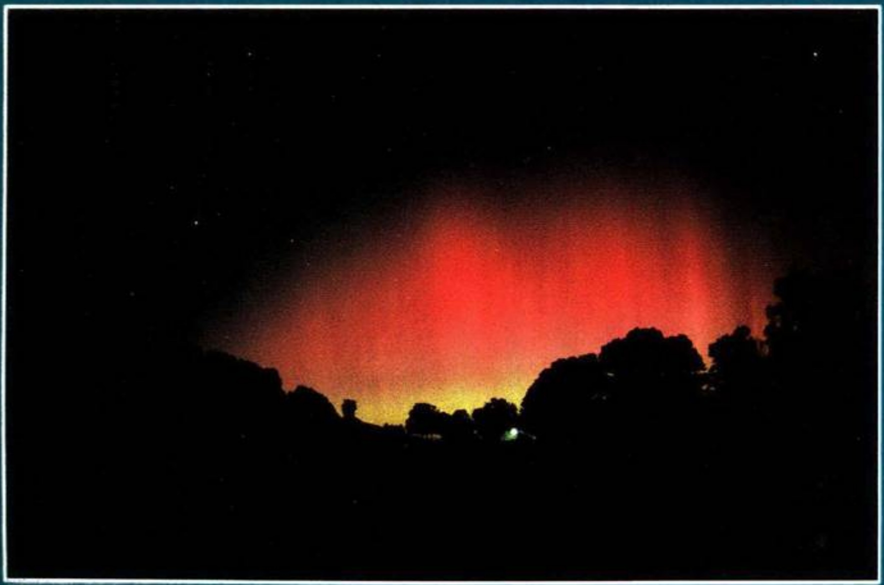
ONE MONTH LATER, on September 29, Okazaki-Levy-Rudenko displayed a tail spanning more than 20′. Photo by Paul Roques.

AN ACTIVE SUN SPARKS AURORAE

With increasing solar activity comes an increase in auroral displays, clearly reflected by numerous recent reader submissions. Richard A. Buchroeder's photograph (right) of an aurora over Tromso, Norway, nets this month's $100 "Best Astrophoto" award. An avid sky photographer living in Tucson, Arizona, Buchroeder caught the show on March 12, 1989, using a 16mm f/2.8 lens, Kodachrome 200 film, and a 20-second exposure. Back in the States, Bernard Volz captured an aurora over North Amherst, Massachusetts, on September 3, 1989, with a 16mm lens and Fujichrome E 1600 film (below).

Other solar system events kept photographers busy last summer and autumn. Josh T. Vaughan of Prescott, Arizona, used a 50mm f/1.4 lens, Fujichrome 100 film, and a 10-second exposure to portray the naked-eye view of the lunar eclipse on August 16, 1989 (bottom). Nova Scuti 1989 flared up near M11 and shone at magnitude 9.7 when photographed by Gene Brings on October 2, 1989 (bottom center). On July 30, 1989, Canadian amateur Terence Dickinson captured an early Perseid meteor as it zipped past the North America Nebula (bottom right).



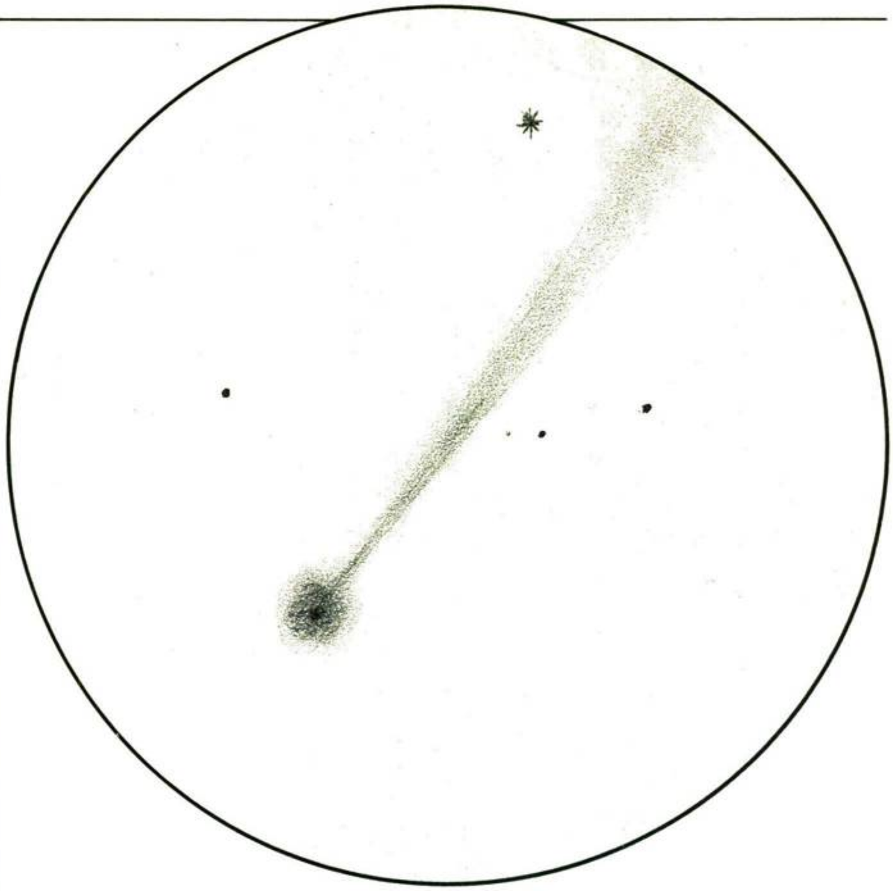


TRAVELS TO THE NORTHERN SKY

"I'm tired of hearing northerners wonder aloud about the fabulous southern sky," said Gregg D. Thompson, of Springwood, Queensland, Australia. "I have just the opposite problem: I've wanted to explore the far *northern* sky for years now." Thompson finally got his wish last summer during an observing session that took place while he was visiting the United States to witness the *Voyager* flyby of Neptune at the Jet Propulsion Laboratory.

"Don't get me wrong," said Thompson. "I've seen some of your wonderful objects — the Owl Nebula, the Double Cluster, and the beautiful spiral galaxy M101 — but from my site near Brisbane they are very low on the horizon.

"After my stay in California," Thompson said, "the opportunity arose to spend an evening observing with James Bryan, an accomplished observer who has a site about thirty-five miles outside of Austin, Texas. After arriving, we wasted no time turning his 16-inch reflector toward M101. Although the galaxy's surface brightness is rather low, I was astonished to see plainly the faint spiral pattern of its



COMET BRORSEN-METCALF showed several overlapping layers of surface brightness when Gregg D. Thompson sketched it in September 1989.

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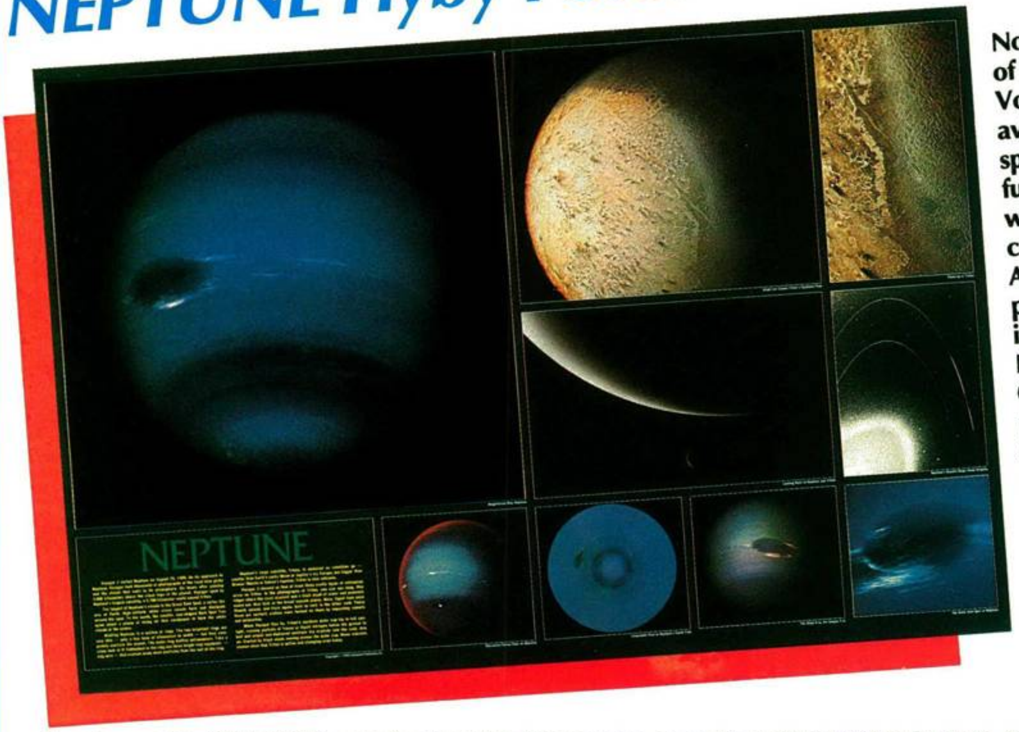

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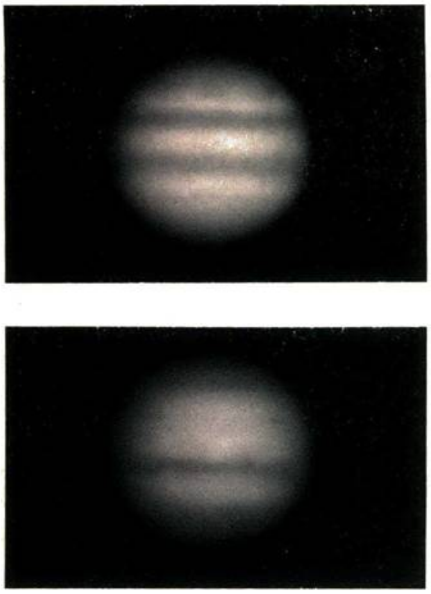

NOW YOU SEE IT, NOW YOU DON'T: Jupiter's South Equatorial Belt appears normal in a photograph made on November 3, 1988 (top). By August 25, 1989, however, the belt had all but disappeared. Photos by Dennis Sorenson (top) and Gregory Terrence.

arms. Needless to say, we observed countless other deep-sky objects and I was stunned by their incredible appearances.

"The observing wasn't limited to deep-sky objects," said Thompson. "Jupiter lacked its usually prominent South Equatorial Belt but showed detail within the Great Red Spot. Comet Brorsen-Metcalf had a condensed, sky-blue coma and a long, smoothly illuminated gas tail. For those northerners who think they must go south to see great objects, I suggest that they have plenty of spectacular sights in their own backyard."

WHERE ARE YOU, SOUTH EQUATORIAL BELT?

Last summer Jupiter's South Equatorial Belt, one of the planet's most conspicuous features, faded to near invisibility. The South Equatorial Belt is one of the planet's two main dark belts and is typically easily visible with a small telescope. Beginning on July 16, 1989, however, planetary observers began to observe a major fading that left the South Equatorial Belt virtually invisible after a few weeks.

On July 19 Guy M. Hurst of Basingstoke, England, reported that two English observers and four Spanish observers determined the fading was centered on longitude 138° (+/−90°). Hurst reported that "only a faint and attenuated belt, probably the northern component of the South Equatorial Belt, was visible." On July 21 J. Sanchez and A. Carrera of Santa Cruz, Tenerife, observed the planet and found that the South Equatorial Belt had "disappeared completely." Eight days later Stephen J. O'Meara of *Sky & Telescope* magazine reported the South Equatorial Belt had not completely disappeared, but had faded dramatically. According to O'Meara, the southern component of the South Equatorial Belt was the darker of the two and appeared "threadlike." The northern component was "fainter, duskier, and irregular."

The fading of Jupiter's South Equatorial Belt is most likely the result of bright material mixing into the darker clouds, thus raising the material's albedo. No one knows how long this effect will last or what Jupiter is likely to look like several months from now. — *David J. Eicher* ☐

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LOGBOOK: VOYAGER 2 AT NEPTUNE

April 1989. *Voyager 2* has worked spectacularly for so long. Can it do it once more at Neptune? The question becomes very serious when we learn of the failure of the second *Phobos* spacecraft the USSR sent to Mars. Can our scientists, engineers, and technicians —along with some good luck — pull off another success for *Voyager*?

May. After doing background research, we discover that scientists have little idea of how large Neptune's two moons are. Estimates for Triton's diameter range from 2,000 to 5,000 kilometers. This means it could be anywhere from the twelfth largest rocky body in the solar system to the sixth largest.

June. Early images of Neptune are striking and show both dark and light spots in a dynamic upper atmosphere. Brad Smith, head of the *Voyager* imaging team, is quoted in the newspaper as saying, "Neptune is now more interesting than Uranus was at close encounter." Scientists have found that the meteorology of each gas giant planet has been less active than the one before it because of the planet's increased distance from the Sun. But Neptune breaks the pattern — the first big surprise of the encounter.

Tuesday, July 11. The local cable company where we live (San Diego) initially claimed, "There's no audience for space discovery." They refused to show NASA's Neptune programs coming down from the satellite feed. However, after we and many others wrote letters and made phone calls to our city council (who renews their license), they relented.

Thus today we sit in our living room and watch a replay of last week's Neptune images. The planet's disk grows larger week by week. Like some exploring ship nearing the end of a long trip, *Voyager* is closing in on its last planet.

Saturday, August 12. The newspapers report that not only have two new moons of Neptune been discovered, but two "ring arcs" have also been spotted. The amount of news coverage, both print and television, surprises us. Excitement is clearly building, not just among space buffs, but even the general public. The spacecraft just keeps doing its job —though its old, crippled, half blind, and very deaf.

Thursday, August 17. Reading about *Voyager* in the daily paper, the average person may think planetary encounters are without risk. But the unknowns in space are vast; scientists and engineers must anticipate everything *Voyager* might face. To us, it looks as if things are going too smoothly. Or has Murphy's Law been repealed for *Voyager*?

Friday, August 18. Closest approach is now less than a week away. Local television reports *Voyager*'s discovery of Neptune's magnetosphere and shows a diagram to illustrate the complex topic. The heavy news coverage and popular interest contrast with the Uranus flyby, which was overshadowed by the *Challenger* disaster.

Monday, August 21; "Opening Day." The first of the daily press conferences is held in Von Karman Auditorium at the Jet Propulsion Laboratory in Pasadena. Electronic flashes pop like heat lightning as news photographers take pictures of Brad

VOYAGER IMAGING LEADER Brad Smith meets the press.

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Smith in front of the images on the big screen. A crew from IMAX operates their cumbersome 70mm camera, shrouded in a soft, puffy "sound blimp" to mute the noise of its motors. They are here to film a movie to be released in 1992, the International Space Year.

The spacecraft engineers report that *Voyager* is in excellent health all in all and right on target after a final course correction early this morning. Neptune's strange spots and clouds cause much discussion. In an ultraviolet image the markings look like a crooked pumpkin face. In another photo the Great Dark Spot has a sort of cloud tail that makes it look like a giant tadpole.

We notice that we don't follow the JPL timeline of scheduled experiments nearly as closely as at the Saturn flyby. Back then, pictures came almost too fast to keep up with. Now, they trickle out slowly because of the low data rate imposed by the enormous distance to Earth and the dim light at Neptune, which is nearly a thousand times fainter than at Earth.

Tuesday, August 22; "Waiting Day." We have to be back in San Diego, so we view the press conferences these next three days from home. Almost nine years ago we wrote in ASTRONOMY, "If things were as they should be, the entire nation, even the world, could have shared minute by minute this odyssey to new lands." We haven't quite achieved that yet, but it's still a stellar experience to view these historic moments in one's living room.

Most of the news released today is partial and preliminary. The big story is that the ring arcs are now downgraded to mere clumps — Neptune, like its other gas-giant siblings, has complete rings.

Wednesday, August 23; "Anticipation Day." The details on Neptune, its rings, and Triton are tantalizing. But the details are not yet clear enough for any conclusions to be drawn. Grilled again and again by reporters, the scientists keep saying, "We don't know. We'll have that data tomorrow."

The rapidly changing cloud features on Neptune prove baffling. New features have to be identified, named, and tracked. Atmospheric scientist Andy Ingersoll says, "It's like a horse race where you can't see the horses at first, and then when you can, you can't identify them."

Thursday, August 24; "Flyby Day." Ed Stone, chief project scientist, opens the press conference by saying, "This is the twenty-four hours we've been waiting for." We learn that Triton, with a diameter of about 2,750 kilometers, is the ele-

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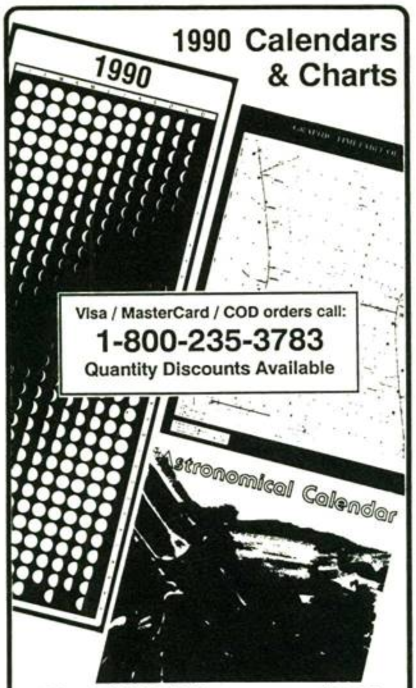

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venth largest rocky body in the solar system. And Nereid is not Neptune's second largest moon after all — the cameras reveal that the diameter of 1989N1 is larger.

A new feature at this flyby is that the computer-generated graphics show how far fast, behind-the-scenes processing has come. At Uranus these images came out in the weeks after encounter — now we're seeing them soon after they are taken.

Thursday-Friday, August 24-25; "Flyby Night." By midnight the scene at JPL is frantic. Random images: an anchorman putting on makeup, reporters splashing water on their faces to stay awake, an interviewee kept vertical by a microphone wire hooked onto his back collar and running to a plug on the seat of his chair, constant dabbing of foreheads under umbrella lights, a Japanese crew doing a morning news show for the other side of the globe, stacks of picnic coolers and paper bags filled with coffee and snacks to keep people going.

Really, there's no good reason to stay up because the hard science won't come in for hours, even days, but we all do it anyway. Later, we learned that between two thousand and three thousand people attended the free, all-night viewing at the Fleet Space Theater back in San Diego; a crowd of five hundred dogged enthusiasts was still there at 3:00 a.m. We poop out at 2:30.

Friday, August 25; "The Morning After." Everyone looks bleary-eyed, but exhilarated. We're up by 8 a.m. when Vice President Quayle arrives. His visit occasioned "rebadging" of the press and many elaborate security measures. He is the highest ranking official ever to visit JPL in the twelve years of the *Voyager* missions. He says a lot of good things about the future of the U.S. space program. But as the old saying goes, talk is cheap. One reporter sums up the general skepticism, "Just be sure to send the check!"

At the morning press conference, Ed Stone says he "couldn't be happier with the outcome," speaking not only of the "scientific success but also the major engineering success." Geologist Larry Soderblom calls it "a gee-whiz day" and notes that Triton is the last object *Voyager 2* will ever examine close-up. "Wow! What a way to leave the solar system," he exclaims happily. Ed Stone calls it "the most exciting night of any *Voyager* encounter." But it clearly took its toll on him and everyone else. The rest of the day feels like a hangover.

Saturday, August 26; "Hard Science Day #1." Everyone looks better today, and the real science briefings begin. Attendance at the press conference is down slightly; the media spotlight has moved onward.

The flood of data collected during closest encounter flows back along its 4 hour, 6 minute electronic path to Earth. Some of the data stored on *Voyager*'s magnetic tape will not be played back for a day or two. Today, we learn about new rings, high cirrus clouds, limb haze, and waves in "Scooter," a little cloud moving rapidly around Neptune's southern hemisphere.

Sunday, August 27; "Hard Science Day #2." Attendance dropped even more today. The original 1,050-plus press contingent is shrinking and the room is colder now, with fewer bodies to absorb the air conditioning's chill. Science news released today includes Neptune's rotational period, the sharp tilt of its magnetic field, the high velocity of winds, and Triton's strange surface.

This evening the Planetary Society throws a party at JPL, with Carl Sagan as host, for everyone who worked on *Voyager*. Sagan ends his brief speech by referring to the music on the golden record on board the spacecraft: "The only living American musician on the record is Chuck Berry." And, unbelievably, at that moment Chuck Berry appears in formal attire and performs a six-song set that has not only many JPL and *Voyager* staffers, but Sagan and Brad Smith, up and dancing. It's an unforgettable moment.

Monday, August 28; "Hard Science Day #3." We're back in San Diego. The cable company has stopped showing the press conferences, so we have to hurry to Fleet Space Theater to catch today's. Interest is still high — the lecture hall has nearly seventy-five people present during the sometimes highly technical science reports. These detail Neptune's internal heat, atmospheric smog, three rings, and dust sheet, as well as Triton's bizarre cryo-volcanism and extremely cold surface with frost deposits.

Tuesday, August 29; "Closing Day." The last of the seventy-five press conferences held during the entire *Voyager* mission is an emotional one, with much thanks, applause, and even some teary, off-camera blowing of noses.

Close-up images of Triton dominate the screen. Brad Smith shows *Voyager 2*'s goodbye to the planets — Neptune's and Triton's crescent shapes back-lit by the Sun.

Finally, Ed Stone closes the conference by quoting T. S. Eliot: "Not farewell / But fare forward, voyagers." — *John and Stephanie Mood* □

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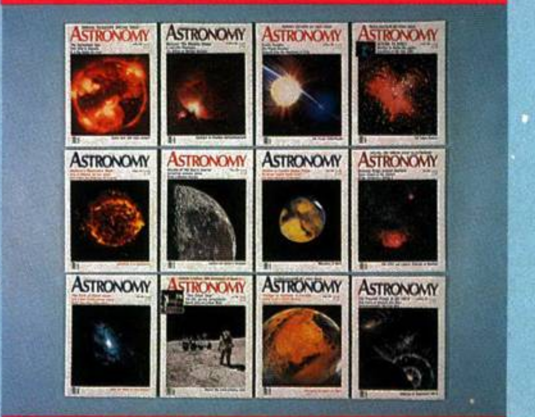

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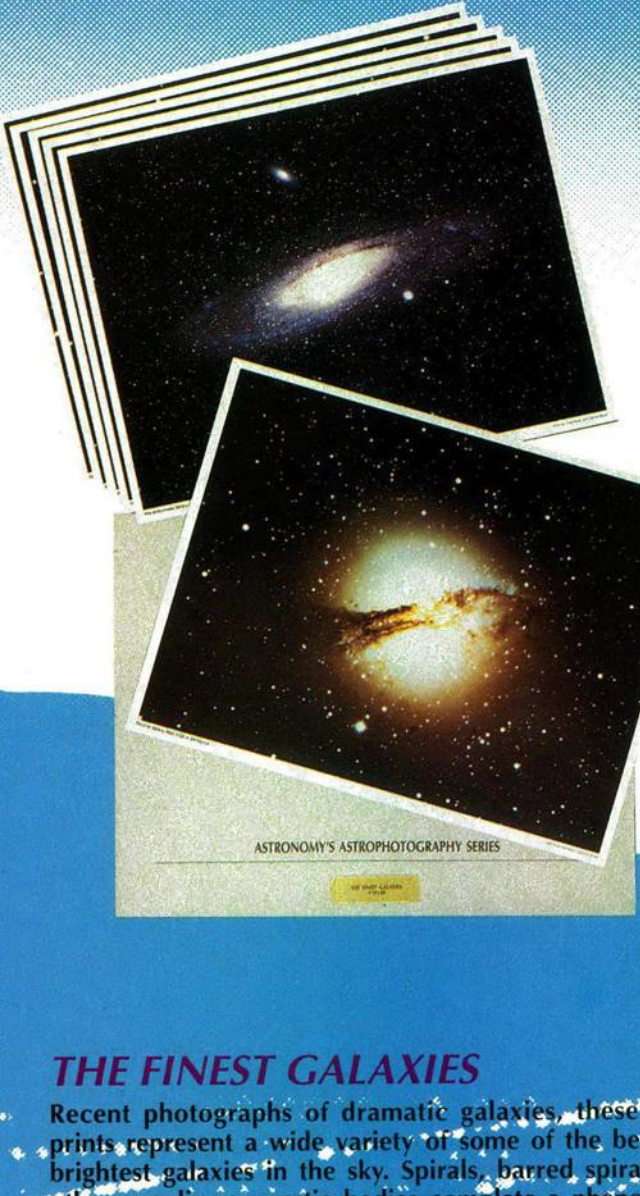

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STORY SHINES THROUGH PEDANTRY

Coming of Age in the Milky Way by Timothy Ferris, (William Morrow and Company, Inc. 1988), ISBN 0-688-05889-2, hardcover, 496 pages, $19.95.

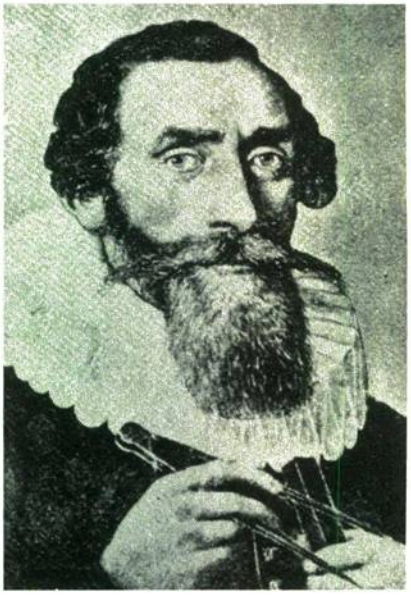
In his preface to *Coming of Age in the Milky Way,* Timothy Ferris writes that the story of how the human race has arrived at its current understanding of the universe is too grand and indomitable to be contained within a book. Unfortunately, Ferris must have realized this too late during his twelve years of research because what we have is a book with a distinctly erudite air that too often obscures, rather than illuminates. Paradoxically, though, it is the subject that ultimately saves this book from itself and makes *Coming of Age in the Milky Way* a worthwhile read.

There are three main sections. Section one addresses the religious, political, and scientific events that led to the various cosmologies of our ancestors and traces the evolution of these concepts up to Edwin Hubble's (and others') discovery of the expanding universe in the early 1920s. On a more geological track, section two traces the path scientists followed to derive the age of the Earth — and the impact of this discovery on religious orthodoxy. With the terrestrial time line thus established, the book then focuses on stellar evolution and the age of the stars. In section three, Ferris tells the story of mankind's recent foray into the uncertain world of quantum mechanics, where unimaginably small particles in the quarky universe have rather sizable effects on the macrocosmic scale.

Given the grandiose subject and the characters involved, the occasional lapses of pedantry may be an unavoidable pitfall. One gets the feeling that Ferris was possessed by his resources as he was writing. Perhaps that is why quotes precede every chapter: Everyone from Thomas Moore and Albert Einstein to Platform Sutra and Ovid has their say. No part of the book has escaped the blizzard of epigrams — even the glossary has collected a small drift, from Vladimir Nabokov: "The breaking of a wave cannot explain the sea." Profound, true. But at the risk of sounding uncouth, I think many readers may cease to be moved after a succession of Shakespeare and esoteric Tahitian creation stories. You can pull the trigger only so many times before you become blase about the "bang."

Still, I can't condemn the book strictly on the basis of its intellectual disposition. For behind the scholarly quotes and high-flown language is *the* story: How our species has struggled to understand the world, the universe, and ourselves. Thankfully, where the scholarly style intrudes, the subject prevails. This is especially noticeable in Ferris' profiles of explorers and scientists — Christopher Columbus' impetuousness, Isaac Newton's eccentricities (particularly fascinating), and Johannes Kepler's travails. Knowing about the human strengths and frailties behind the legends makes their discoveries all the more astonishing.

Ferris' *Coming of Age in the Milky Way* may not be as readable as *The Red Limit,* but it is good science and, at times, good drama. It would have been a better book, though, if the author had been less pedagogical so that the fascinating interplay between mind and nature was more evident than the style in which it was presented. — *Jeff Kanipe*



JOHANNES KEPLER is one of the many pioneer astronomers profiled in Timothy Ferris' book *Coming of Age in the Milky Way.*

AN ALL-ENCOMPASSING ATLAS

The Cambridge Atlas of Astronomy, Second Edition, Jean Audouze and Guy Israel, editors, (Cambridge University Press, 1988), ISBN 0-521-36360-8, hardcover, 432 pages, $90.

When you look at the price of this massive book, you have to ask yourself: is it worth it? The answer is yes, I think so — well, it depends.

On the one hand, the atlas covers practically all fields in astronomy — from solar system astronomy and astrophysics to cosmology and the history of astronomy. From front to back it is rich in the latest in astronomy research and images and contains colorful diagrams and treatments of recent data gleaned from observatories, satellites, and rocket-borne instruments.

On the other hand, the wide coverage and timeliness make this book, like all references, age more quickly than single-topic books. In less than three years, for example, the chapters on cosmology and astrophysics, particularly those on active galaxies and the distance scale, will need revising as results from the *Hubble Space Telescope* break onto the scene. I'm also a bit concerned about how well infrared astronomy is represented in the atlas, given that *IRAS* results occupy most of the discussion. And the Neptune chapter, written long before *Voyager,* is practically a write-off.

Nonetheless, knowledge is knowledge, no matter how ephemeral (or expensively packaged). Unquestionably, the Cambridge atlas covers the width and breadth of modern astronomy and is a good place to get one's bearings on the many directions in which research is going. The articles are comprehensive and not overly technical (though the nine-point typeface, for a 10x14 book, is a bit too small — especially three-columns worth). An illustrated glossary and a set of sky maps are included at the back of the book. Readers will also appreciate the colorful and well-thought-out graphics and, of course, the beautiful four-color and black-and-white photographs. Despite the sweeping changes already evident on the astronomy horizon, the atlas is still worth the cost. — *Jeff Kanipe*

THE DIRECTION OF COSMIC-RAY RESEARCH

Cosmic Rays: Tracking Particles from Outer Space by Michael W. Friedlander, (Harvard University Press, 1989), ISBN 0-674-17458-5, hardcover, 160 pages, $27.50.

The endless rain of cosmic rays that penetrates our bodies from the far reaches of space has a lot to say about the universe beyond the solar system. *Cosmic Rays* details what astrophysicists know about these enigmatic particles and what they are doing to unlock their secrets. Friedlander looks at the history of cosmic-ray research, how they were iden-

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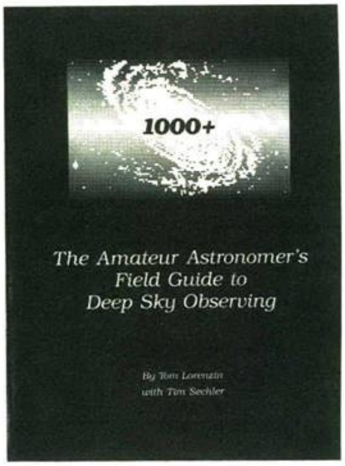
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tified, and the subsequent search for their origins. Chapters discuss what cosmic rays are telling us about the Sun as well as explosive events in our Galaxy. Although somewhat technical (the subject cannot be conveyed without some atomic physics), the text never strays from its popular bias. Included are more than fifty drawings and photographs. The thorough, up-to-date coverage of this subject in one volume makes this a unique reference for the layman and scientist alike. — *Jeff Kanipe*

HOW BIG, HOW FAST, HOW FAR?

How Big is it Really? by Leonard J. Hadden, (Vantage Press, 1988), ISBN 0-533-07697-8, hardcover, 145 pages, $14.95.

I was prepared to dislike this book when it first arrived, mainly because it is from a vanity publishing house. But I took a look anyway and was pleasantly surprised. Hadden's book is essentially an examination of the sizes, temperatures, velocities, etc., of objects in the universe from the perspective of the everyday world. Thus, the book has chapters such as "How Big Is It?", "How Fast Does It Go?", and "How Far Is That Star?" Compared with other books from vanity presses, this one is remarkably well done. The idea is good and the science is sound, though Hadden's facts often go unsubstantiated (sources are not cited). The graphic treatment is crude, but it works on an intuitive level. As long as the facts are double checked, the book would probably make a handy reference for grade-school teachers addressing some of the physical concepts of the universe. — *Jeff Kanipe*

NEW AND UNPOPULAR IDEAS

New Ideas in Astronomy, F. J. Bertola, Jack W. Sulentic, and Barry F. Madore, editors, (Cambridge University Press, 1988), ISBN 0-521-34562-6, hardcover, 349 pages, $54.50.

This book will no doubt make some professional astronomers cringe, but in a roundabout way, that is its stated purpose: "an affirmation of the value of new and sometimes unpopular ideas."

New Ideas is a compendium of papers from a conference held in May 1987 in Venice to honor astronomer Halton Arp on his sixtieth birthday. The name Arp is synonymous with "maverick," according to many astronomers. Among other things, Arp holds that galaxy and quasar redshifts cannot be explained as being cosmological in nature — that is, redshifts are not good indicators of distance because they may be caused by factors other than the expansion of the universe. Arp bases his theory on many examples of galaxies and quasars that appear to be associated in space but exhibit "discordant redshifts" — the galaxy usually has a lower redshift than the quasar or quasars. Consequently, given the man being honored, this book features some highly controversial papers by, sometimes, equally controversial authors: "Is the Universe Fundamentally Biological?" by Fred Hoyle; "Tests of the Discordant Redshift Hypothesis" by Jack Sulentic; "Ejection Mechanisms in Galaxies" by William Saslaw; and "Difficulties of Standard Cosmologies" by J. C. Pecker. More standard papers are included, but the spirit of looking at the universe from a fresh perspective clearly prevails. This refreshing collection of rebel ideas, iconoclasms, and blasphemies should be read by every professional and amateur astronomer, if for no other purpose than to challenge his or her thinking. — *Jeff Kanipe*

SUPERNOVA 1987A

Supernova! by Donald Goldsmith, (St. Martin's Press, 1989), ISBN 0-312-02647-1, 208 pages, hardcover, $15.95.

Another book on Supernova 1987A! But given the rarity of nearby supernovae and the tidal wave that has since washed across what was once considered a fairly established regime in astronomy, many more books could yet be written about what is known, theorized, and speculated about supernovae. Donald Goldsmith focuses mainly on the galvanizing effect 1987A has had on modern astronomy, but he also ties humanity's fascination with supernovae into the greater historical perspective. He cites milestones in supernova history, from ancient Chinese records of the purported "guest star" of A.D. 185, Tycho Brahe's meticulous observations of the supernova of 1572 (of which Brahe produced the first accurate light curve), and the telescopic observations of the supernova in the Andromeda Galaxy in 1885. Chapters also cover stellar death, supernova byproducts (neutron stars, pulsars, and black holes), and supernovae as probes of the universe.

One of the better chapters is "What Makes a Supernova Shine?" By studying radiation emitted by 1987A at all wavelengths, astronomers have for the first time been able to verify their theories as to how supernovae can produce their intense light. In clear, cogent terms, *Goldsmith explains how the* "intimate association" of nickel, cobalt, and iron makes supernovae shine with the light of a 100 billion suns.

Supernova! is an absorbing and elegantly written chronicle of the scientific aftermath of 1987A, addressing its role in unraveling the mysteries of exploding stars as well as the new questions it raises. All this makes *Supernova!* superlative reading for both professional and amateur astronomers. — *Jeff Kanipe*

AMATEUR ASTRONOMY

Dictionary of Astronomical Names by Adrian Room, (Routledge, 1989), ISBN 0-415-012988, hardcover, 282 pages, $27.50.

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Starfield Sky Atlas Overlays, (Christian Legrand, 260 Route de la Bellevue, 76160 Preaux, France); 25 francs (about $4) for the *Sky Atlas 2000.0* version; 35 francs (about $5.50) for the *Uranometria 2000.0* version; prices are air-mail postpaid.

Starfield overlays are sheets of thin, clear plastic acetate with concentric circles drawn on in black ink. The circles have angular diameters of 1° to 7° in 1° steps (*Uranometria* version) and 2° to 10° in 2° steps (*Sky Atlas* version).

When the overlay is placed on an atlas chart, the circles let you see at a glance which stars and other objects will fit within a given field of view.

COMET NEWSLETTER

***Comet Watch* Newsletter,** (David Chandler, P.O. Box 309, La Verne, CA 91750), fifteen issues, $10.

Comet Watch is an irregularly issued newsletter that publishes orbital elements and positional predictions for newly discovered comets. (This information is available to any subscriber to the IAU telegram cards. The IAU telegrams appear more quickly, but they are also more expensive.)

Each issue of *Comet Watch* is a single sheet of 8 1/2- by 11-inch paper with the orbital and observational data on the front. A star map showing the comet's track is printed on the back.

The text includes some information on visibility, and Chandler provides a computer-generated stereograph of the comet's path past Earth — a unique feature of this newsletter. (To view the stereograph, Chandler sells a simple viewer for $3.) Five issues have been published between September 8 and October 14, 1989.

1990 CALENDAR

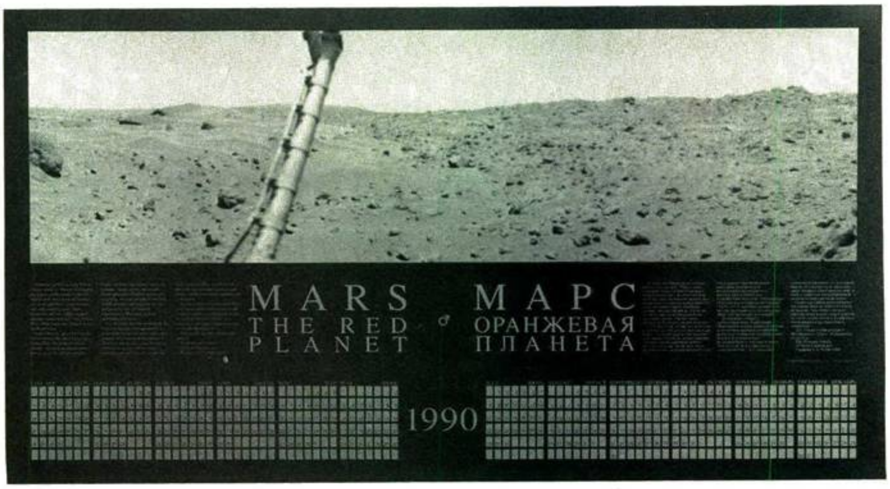
***Mars the Red Planet* calendar**, (Mondotronics, 1014 Morse Avenue, Suite 11, Sunnyvale, CA 94089), $9.95.

Mars the Red Planet is a bilingual (English-Russian) poster-calendar for 1990. It measures 15 by 27 inches and is printed in gold on a red background. The photo shown is a color view from the *Viking 1* lander. The text, printed in both English and Russian, describes the unmanned missions that have gone to Mars as well as The Planetary Society's "Mars Declaration," a proposal for a multinational exploration of the Red Planet.

EDUCATIONAL SOFTWARE

Planets in the Classroom, version 2.0, (David Chandler, P.O. Box 309, La Verne, CA 91750), software for Apple II+/IIe and IBM PCs and true compatibles, one 5 1/4-inch floppy disk plus 17 page manual, $39.

I liked *Planets in the Classroom*. It isn't the snazziest piece of software on the market, and it doesn't do many complicated things. Rather, it does a few simple things very well. For any starting date you choose, it plots the positions of the planets (out through Saturn) either heliocentrically or geocentrically. It can also draw



A SUNNY MARTIAN AFTERNOON glows orange in this bilingual calendar for 1990.

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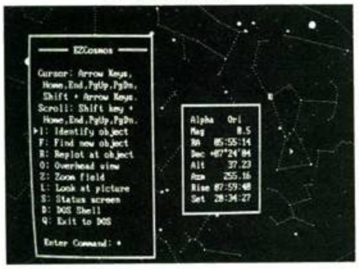

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EZCosmos
Cursor: Arrow Keys,
 Home,End,PgUp,PgDn,
 Shift + Arrow Keys.
Scroll: Shift key +
 Home,End,PgUp,PgDn.
▸I: Identify object
 F: Find new object
 R: Replot at object
 O: Overhead view
 Z: Zoom field
 L: Look at picture
 S: Status screen
 D: DOS Shell
 Q: Exit to DOS

 Enter Command: •
```

```
Alpha   Ori
Mag      0.5
RA  05:55:14
Dec +07°24'04
Alt    37.23
Azm   255.16
Rise 07:59:48
Set  20:34:27
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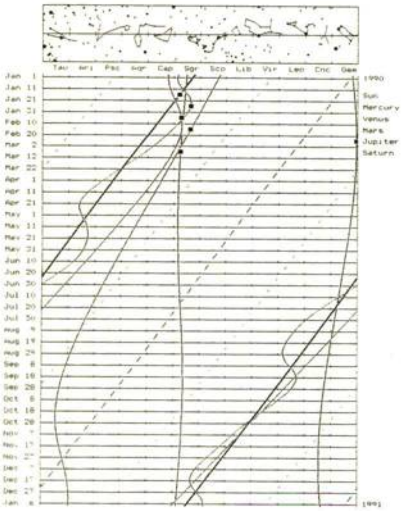
a chart of the ecliptic and locate the planets along it. Finally, it can plot the planets' elongations relative to the Sun.

The program is almost defiant in the way it shuns fancy screen graphics. The user zeroes in on the desired result by means of nested menus, a process that takes a few seconds. Once the final choices are made, the computer spends about thirty seconds plotting the points and then starts sending the results to the printer.



PLANETS AND SUN dance through the zodiac for 1990. (Diagram from *Planets in the Classroom* computer software.)

No colorful screen dumps here, no whiz-bang graphics — all the output channels through a plain old Epson/IBM compatible nine-pin printer, which you must have to run the software. Printouts typically take several minutes and can be interrupted at any point in the printing.

Who would find this program most useful? I don't think it's the kind of software that a total beginner would want to buy for him or herself. The output is a little too abstract. On the other hand, anyone interested in seeing where planets are going to be for a year or more will find the program very helpful.

Another potential user is addressed in the software's name: a teacher conducting an astronomy class. People completely new to astronomy often have difficulties understanding how the planets move, especially in a heliocentric way. (Who says the geocentric solar system is dead?) Some people still find it very hard to understand planetary motions, and *Planets* does an excellent job of making these clear.

The manual takes the user through the various routines and explains their output. The manual also suggests exercises that will help beginners understand planetary motion better and gives step-by-step directions for carrying out the exercises. This is a good and useful program. — *Robert Burnham*

Spacetime, (Physics Academic Software, American Institute of Physics, 335 East 45th Street, New York, NY 10017, (800) 247-7497); for IBM PC, XT, AT, PS/2 computers, one 5 1/4-inch floppy disk, no price given.

Spacetime needs 512K of RAM and a CGA, VGA, or EGA monitor. The software is intended primarily for university-level courses in physics. It is designed to model the effects of relativistic motion by providing graphic demonstrations of the changes induced by velocities near the speed of light. The lab exercises include trips to Alpha Centauri and Canopus, the "train paradox" (which explores simultaneity), and the Lorentz contraction, among others.

The software comes with user's and instructor's manuals that explain how to use the programs and interpret the displays.

ASTRONOMICAL SOFTWARE

EZCosmos, (Future Trends Software, P.O. Box 3927, Austin, TX 78764-3927), for IBM PCs and compatibles, two 5 1/4-inch floppy disks, $29.95.

EZCosmos displays the sky as seen from any given location on Earth; its lunar and planetary ephemeris accepts dates from 1600 to 2400. It requires 512K of RAM and a Hercules, CGA, EGA, or VGA monitor.

The program is menu-driven, and a typical sky display shows a large region (roughly a quarter of the entire visible sky). The screen takes about a minute to plot using a Hercules monitor; replotting the screen to center an object takes about thirty seconds.

The program provides a small, hollow box cursor, the position of which is controlled by the scroll keys. When you place the cursor over an object on the screen and hit ENTER, the software identifies the object and provides a short list of data about it (right ascension and declination, rise and set time, distance, magnitude, and so on).

PRODUCT UPDATE

The publisher of *DEEPSKY 2000* (reviewed in the October issue) informs us that the price of the software is now $29.95; the current version is 2.0. ☐

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Readings and Resources

New Era in Space (page 22)
Office of Space Science and Applications Strategic Plan 1989, (U.S. Government Printing Office, 1989). An overall assessment of individual missions and goals for NASA's next decade in space.

Seeing the Unseen Sun (page 30)
The New Solar System, edited by J. Kelly Beatty, Brian O'Leary, and Andrew Chaikin, (Cambridge University Press and Sky Publishing Corporation). The chapters "The Sun" and "Magnetospheres and the Interplanetary Medium" provide a general background on *Ulysses'* mission.

The Space Telescope (page 38)
"From Idea to Observation: The *Space Telescope* at Work" by Ray Villard, ASTRONOMY, June 1989. Explains the complex process by which a proposal for observing time on the *Hubble Space Telescope* is turned into scientific data.

Bound for Jupiter (page 46)
Galileo: Exploration of Jupiter's System, (NASA-SP-479), by Torrence Johnson, et al. A detailed pre-*Challenger* accident account of every aspect of the *Galileo* mission. Although it is rather out of date and technical, its copious illustrations and comprehensiveness make this a good source.

The Horsehead Nebula (page 82)
Burnham's Celestial Handbook by Robert Burnham, Jr., (Dover Publications, 1978). Volume two in this three-volume set covers Orion and includes useful background material on the Horsehead Nebula.

The Perfect Planet (page 88)
Observing and Photographing the Solar System by Thomas A. Dobbins, Donald C. Parker, and Charles F. Capen, (Willmann-Bell, Inc., 1988). Specific advice on how to observe and photograph objects in the solar system.

Comet Brorsen-Metcalf (page 96)
Comets: A Descriptive Catalog by Gary W. Kronk, (Enslow Publishers, 1984). Contains an alphabetical list of data on comets including Brorsen-Metcalf. ☐

CREDITS

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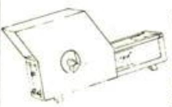

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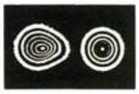

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January 9-13
The 1990s: A New Decade for Astronomy, Crystal City Gateway Marriott, Crystal City, Virginia. Sponsored by the American Astronomical Society. Contact: American Astronomical Society, 2000 Florida Avenue, NW, Suite 300, Washington, DC 20009.

January 13
Astronomy Day 1990, Pine Mountain, Georgia. Sponsored by the Patterson Planetarium and Callaway Gardens. Contact: Patterson Planetarium, 2900 Woodruff Farm Road, Columbus, GA 31907. Phone: (404) 568-1730.

January 25-28
6th Annual Winter Star Party, Florida Keys, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Tippy D'Auria, 1051 N.W. 145th Street, Miami, FL 33168. Phone: (305) 685-6001.

March 22-25
3rd Annual Chiefland Star Party, Chiefland, Florida. Sponsored by the Tampa Area Astronomy Society. Contact: John Novak, 9890 82nd Street North, Largo, FL 34627. Phone: (813) 392-4669 or (904) 493-9036.

April 24-27
27th Space Congress, Cocoa Beach, Florida. Sponsored by the Canaveral Council of Technical Societies. Contact: Canaveral Council of Technical Societies, P.O. Box 321333, Cocoa Beach, FL 32932.

May 20-28
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: TSP Registrar, Department A, P.O. Box 386, Wylie, TX 75098.

July 13-15
Symposium on Automated Telescopes and Global Networking, Boston University, Boston, Massachusetts. Contact: Meeting Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

July 14-15
The Universe in the Classroom, Boston University, Boston, Massachusetts. Contact: Workshop Information, Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

July 8-21, 1991
Research Amateur Astronomy Symposium, La Paz, Baja California Sur, Mexico. Contact: Corporation for Research in Amateur Astronomy, P.O. Box 16542, San Francisco, CA 94116.

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information. ☐

READER EXCHANGE

WANTED — 6" or larger binocular telescope. Must be portable. Contact N. Zadra, 4206 North Prospect Avenue, Shorewood, WI 53211. Phone (414) 962-3021.

WANTED – Meade 2120 LX5 with accessories. Phone Joe Mortell at (312) 297-4542.

WANTED — VHS tape of "A Conversation with Carl Sagan" from CNN (May 5, 1989) and PBS Special "The Creation of the Universe." Also, any material on video about supernova 1987A. Contact R. D., 131 Sycamore Drive, Manhasset Hills, NY 11040.

FOR SALE — Copernicus stamps. First day cover signed by Clyde W. Tombaugh. $50. First day cover signed by Tombaugh and Charles T. Kowal. $60. Contact Tim Horton, 1245 East Avenue J-12, Lancaster, CA 93535.

WANTED — Remote declination control for older-model C8 telescope. Phone Steve Dunk at (512) 654-7664 (evenings).

WANTED — Someone to grind and figure a 15x2 mirror. Need a high quality f/5 to f/6, 1/12th wave or better. Willing to trade a second blank or pay. Contact Muskegon Astronomical Society, P.O. Box 363, Muskegon, MI 49443.

FOR SALE — ASTRONOMY. August 1973-December 1988. *Sky & Telescope.* January 1972-December 1988. All in mint condition. $275 for each set plus shipping. *Star and Sky.* January 1979-February 1981. Mint condition. $50. Contact Steve Reed, 5161 South Flower Street, Littleton, CO 80123. Phone (303) 972-8994.

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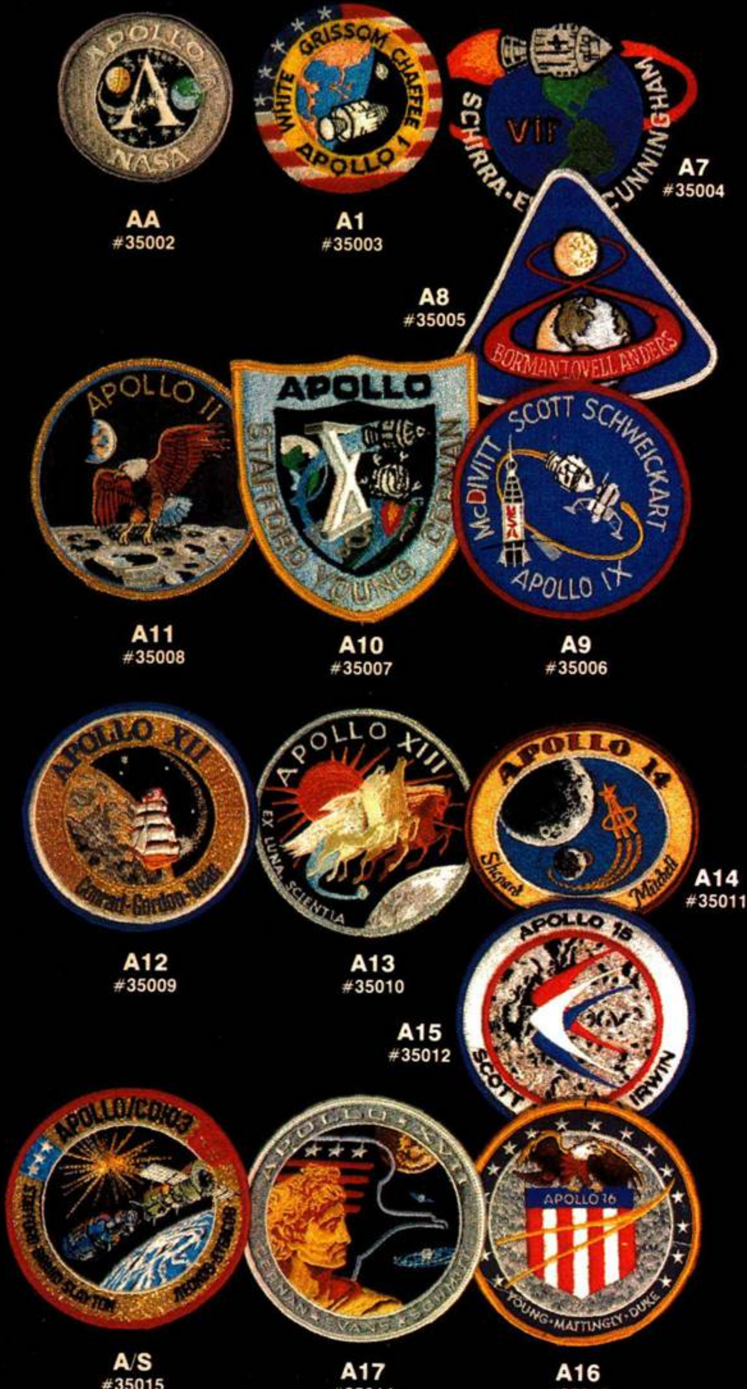

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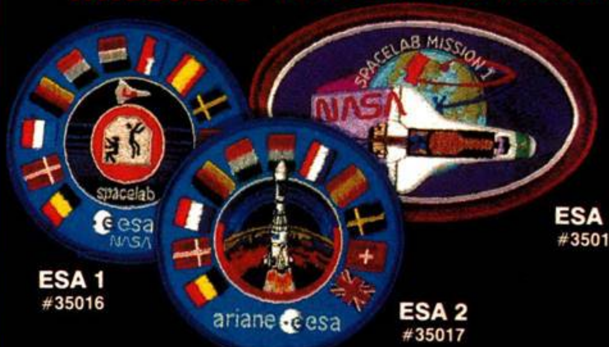

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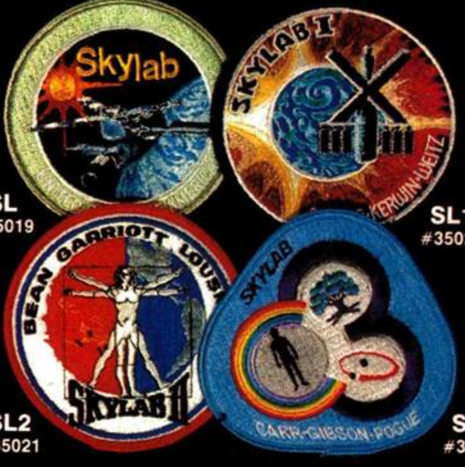

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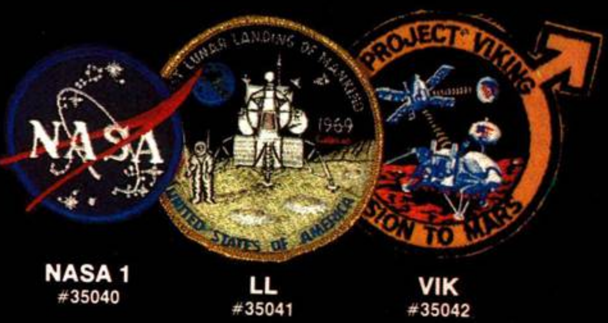

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COMING IN THE FEBRUARY 1990 ISSUE OF ASTRONOMY

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AVAILABLE ON YOUR NEWSSTAND JANUARY 16

— Addendum —

Astronomy equipment suppliers omitted, in error, from our October 1989 directory:

Ashley Center Studio Inc.
226 N. 1500 W.
Vernal, UT 84078
(801) 789-6121
Telescopes, accessories and observing aids.

Astronomical Society of the Pacific
390 Ashton Avenue
San Francisco, CA 94112
(415) 337-1100
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Steve Bryant
4665 Old Easton Road
Doyleston, PA 18901
(215) 348-0593
Computer Software.

Celestial Systems
2428 Jefferson Street
Napa, CA 94558
(707) 224-3195
Telescopes, accessories and observing aids.

Cooter's Village Camera Shops, Inc.
12 Highland Park Village
Dallas, TX 75205
(214) 521-4553
Telescopes, accessories and observing aids.

Cygnus
P.O. Box 69052, Station K
Vancouver, BC V5K 4W3
(604) 432-7731
Computer Software.

Eastern Hills Camera
7875 Montgomery Rd.
Cincinnati, OH 45236
(513) 791-2140
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Firefly Books Ltd.
250 Sparks Avenue
Willowdale, Ontario M2H 2S4
(416) 499-8412
Books and publications.

Hobby House
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Las Vegas, NV 89104
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Telescopes and accessories.

MMI Corporation
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Baltimore, MD 21211
(301) 366-1222
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Mr. Telescope
2071 E. Camelback
Phoenix, AZ 85016
(602) 955-5521
Telescopes, accessories and observing aids.

Orange County Astronomers
2215 Martha Avenue
Orange, CA 92667
(714) 639-8446
Books and publications.

Orbit Book Company
P.O. Box 9542
Melbourne, FL 32902-9542
(407) 724-9542
Books and publications.

P.A.P. Coating Services
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Anaheim, CA 92802
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Mirror coating.

Play For Keeps
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Kansas City, MO 64108
(816) 842-8697
Books and publications, science products, star maps and atlases.

Richmond Enterprises
2664 Barbey Drive
Salt Lake City, UT 84109
(801) 485-3970
Computer Software

Sky Instruments
MPO Box 3164
Vancouver, BC V6B 3X6
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Telescope manufacturer.

Versacorp
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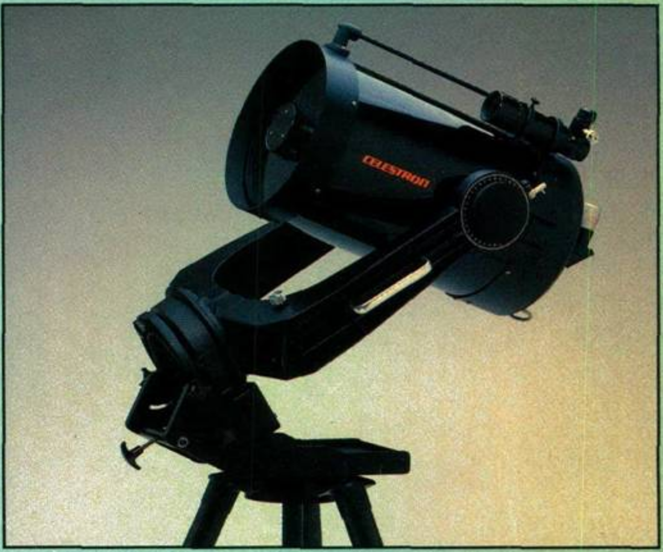

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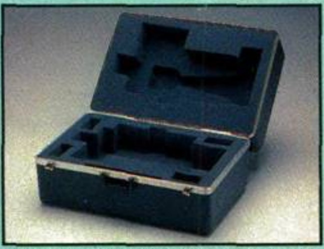

Ultima® 11: Deluxe foam fitted carrying case.

CASTINGS Completely new castings including among others, the rear and front cells and fork tines (twice as large as competitive units). The rugged castings complement the Ultima's large aperture and make viewing and astrophotography a delight.

CARRY HANDLES Setting up and moving the telescope is easy with the carrying handles on both fork tines and the rear cell.

DRIVE SYSTEM The Ultima® 11 utilizes the drive system base from the successful Ultima® 8. The totally cordless quartz-locked electronic drive system has rechargeable heavy duty industrial grade sealed lead acid batteries (good for 500 charges from AC or DC). No excess wires, cords, etc. Also included is the Byers worm gear drive system (the most accurate of commercial Schmidt-Cassegrain's with its 7.54″ diameter and 359-tooth gear (30% larger and twice as many teeth as competitive units). The polar axis ball bearings are precision loaded and 4″ diameter. The polar shaft is integrally cast into the base and is much larger and more stable than other units on the market.

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